MISSION OPERATIONS AND DATA SYSTEMS DIRECTORATE

Landsat-7

Image Assessment System (IAS)

System Design Specification

December 1996

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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Preface

This system design specification contains the highest level design information for the IAS. The IAS system design is based on an analysis of the requirements contained in the IAS Element Specification and associated Interface Control Documents and results from various technical analyses performed by the IAS Project. This IAS system design specification, once baselined at/after the Delta System Design/Preliminary Design Review (Delta SDR/PDR), will be controlled by the IAS/LPGS Project Management Control Board (PMCB) and maintained and updated, as required, by the IAS Project.

This system design specification was prepared for:

Landsat 7 Image Assessment System Project
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Abstract

The Landsat 7 Image Assessment System (IAS) provides the Landsat-7 Program with the capability to assess the quality of the Level 0R datasets being distributed to users by the EROS Data Center (EDC) Distributed Active Archive Center (EDC DAAC) and to calibrate the on-orbit radiometry and geometry of the Landsat-7 Enhanced Thematic Mapper + (ETM+) instrument and satellite. The IAS receives Level 0R products from the EDC DAAC and processes them to Level 1G. Data from onboard calibration sources and special geometric test site scenes are processed to revise calibration (correction and registration) parameters. The resulting parameters are provided to the DAAC for generation of Level 1 products and for distribution to users ordering Level 0R ETM+ data. The system design presented in this document is based on the requirements contained in the IAS Element Specification and associated Interface Control Documents.

Keywords: *Landsat 7 Image Assessment System (IAS), Geometric calibration, Radiometric calibration, Evaluation and Assessment, EDC Distributed Active Archive Center (EDC DAAC)*

IAS System Design TBD/TBR List

The following items pertaining to IAS System Design are still to be determined (TBD) and/or to be resolved (TBR):

1. Definition of all radiometric and geometric algorithms to be accommodated within the IAS

2. Definition of the content and format of the Calibration Parameter File

3. Definition of the content and format of IAS reports

4. Definition of required IAS error handling capabilities, including identification of Level 1 and Calibration error conditions, associated level of severity, and action to be taken (automated or manual)

5. Definition of the MMO interface

6. Resolution of Level 0R Product searchable metadata fields available at the DAAC

7. Data retention and archival strategy

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Section 1. Introduction

The Image Assessment System (IAS) is an element of the Landsat-7 Ground Data Handling Segment. The primary objectives of the IAS are to

- Assess the quality of a small sample of the Level 0R data archived by the EROS Data Center (EDC) Distributed Active Archive Center (DAAC)
- Calibrate the on-orbit radiometry and geometry of the Landsat-7 Enhanced Thematic Mapper + (ETM+) instrument and satellite
- Provide the resulting correction and registration parameters to the DAAC for generation of Level 1 products, for distribution to users ordering Level 0R ETM+ data, or in response to user requests for the parameters

To meet these objectives, the IAS must perform the following functions:

- Radiometrically correct and geometrically register Level 0R ETM+ data to create Level 1 digital image data
- Perform radiometric calibration
- Perform geometric calibration
- Evaluate data quality
- Report results to the DAAC, Landsat-7 Processing System (LPS), and the Landsat-7 Mission Operations Center (MOC)

1.1 Document Purpose and Scope

The purpose of this document is to establish the system design for the Landsat 7 Image Assessment System (IAS). The IAS system design is based on an analysis of the requirements contained in the *Landsat 7 Image Assessment System (IAS) Element Specification* and applicable Interface Control Documents (ICDs). It also incorporates the results of previous design work and prototyping studies performed by the IAS Project at EDC.

1.2 Document Organization

The remainder of the document is broken into four major sections followed by three Appendixes.

Section 2 presents the System Design Overview. This overview includes the list of requirements drivers, design assumptions and constraints, and issues. It then introduces the IAS system architecture, identifying the IAS hardware and software configuration items.

Section 3 presents the System Design which defines each of the IAS subsystems. Subsystem descriptions include listings of allocated system-level and derived requirements, definitions of subsystem interfaces, and descriptions of the functional decomposition of the subsystem. Subsystem use of system hardware and support software is also described.

Section 4 describes how System Support Software will be used to satisfy IAS system requirements. System support software includes both traditional system software (e.g., operating systems) as well as Commercial-Off-The-Shelf (COTS) and Non-Development Item (NDI) software.

Section 5 presents operations scenarios that demonstrate how the system design is used to perform required operations.

Appendix A presents the IAS Requirements Allocation Matrix depicting the allocation of each of the requirements in the *IAS Element Specification* to individual IAS subsystems, hardware, or operations. Appendix B presents the Entity-Relationship Diagrams for the Oracle database. Appendix C presents the Standard Processing Flow Diagrams. These show the sequence of IAS applications to be invoked for each type of image received by IAS.

1.3 IAS-Related Documents

1.3.1 Applicable Documents

The following documents contain requirements that impact the IAS design.

1. National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC), 430-15-01-001-0, *Landsat-7 Image Assessment System (IAS) Element Specification*, October 1996.

2. NASA/GSFC, 430-11-06-007-0, *Landsat 7 0R Distribution Product Data Format Control Book HDF Version*, July 2, 1996 Review Draft.

3. NASA/GSFC, 430-15-01-002-0, *Landsat 7 Calibration Parameter File Definition*.

4. NASA/GSFC, 430-L-0002-H, *Landsat 7 System Specification*, August 1994.

5. Computer Sciences Corporation, *Landsat-7 Mission Operations Center (MOC) to Image Assessment System (IAS) Interface Control Document (ICD)*, November, 1995.

6. NASA/GSFC, 514-1ICD/0195, *Interface Control Document (ICD) Between the Image Assessment System (IAS) and the Landsat-7 Processing System (LPS)*, January 31, 1996.

7. Hughes Information Technology Systems, 209-CD-013-003, *Interface Control Document Between EOSDIS Core System (ECS) and the Landsat 7 System*, March 1996.

1.3.2 Reference Documents

The following documents contain additional background information related to the Landsat-7 mission and to IAS.

1. NASA, *Landsat 7 Level 1 Requirements*, Draft Issue, August 8, 1994.

2. AlliedSignal Technical Services Corporation, *Landsat 7 Detailed Mission Requirements*, March 1996.

3. Martin Marietta Astro Space (MMAS), *Landsat-7 Image Assessment System Operations Concept*, September 1994.

4. NASA GSFC, 430-11-06--003-0, *Landsat 7 System and Operations Concept*, October 1994.

5. MMAS, CDRL No. A104, *Space Segment Calibration Plan*, August 1994.

6. MMAS, 23007702, *Landsat 7 System Data Format Control Book (DFCB) Volume 4 - Wideband Data*, December 2, 1994.

7. MMAS, CDRL #A058, 23007610A, *Landsat-7 Program Coordinate System Standard*, *Rev. B*, December 1994.

8. United States Geological Survey (USGS)/National Oceanic and Atmospheric Administration (NOAA), *Index to Landsat 7 Worldwide Reference System (WRS),* 1982.

Section 2. System Design Overview

This section provides an overview of the IAS system design. It presents first the requirements that significantly drive the system design, as well as design assumptions and constraints and open issues that have a potential impact on the system design. The section then presents the top-level hardware and software architectures and introduces the IAS subsystems.

2.1 IAS Design Drivers

A design driver is defined as a key system requirement that significantly affects the IAS system architecture, hardware or software design, or the operations approach. Changing such a requirement would have a noticeable impact on the IAS system functionality or design.

The following requirements are IAS design drivers:

a) Ingest and store the equivalent of 10 Level 0R scene products per day from the EDC DAAC.

b) Create the equivalent of 10 Level 1G systematically corrected scenes from Level 0R products each day.

c) Perform data quality and ETM+ instrument performance assessments and evaluations with a TBR frequency. Generate and distribute associated reports.

d) Provide a capability for performing trending analysis over time for each selected evaluation activity.

e) Calibrate the radiometric response of each ETM+ detector using Internal Calibrator (IC), Partial Aperture Solar Calibrator (PASC), Full Aperture Solar Calibrator (FASC), and Ground-Look Calibration (GLC) data.

f) Calibrate the radiometric response (absolute radiometric radiance) of each ETM+ detector to 5%, 1 sigma.

g) Perform geometric modeling and resampling to create a systematically-corrected image with a geodetic accuracy of 250m, 1 sigma.

h) Maintain and distribute the Landsat-7 Calibration Parameter File on a quarterly basis, at a minimum.

i) Provide capabilities to support anomaly assessments, resolution, and reporting.

j) Permit operator selection of the processing to be applied to ingested data sets.

k) Provide 100 GB of on-line storage for imagery.

l) Maintain a system Operational Availability of 0.85 and a MTTR of 12 hours.

m) Support software development or maintenance and integration into the operational environment without impacting ongoing operations.

2.2 IAS Design Assumptions

A design assumption is defined as a statement with significant consequence for the design which is accepted as true but which cannot be traced to baselined project documents. The IAS design incorporates the following design assumptions:

a) The geometry and radiometry subsystems will be designed for direct plugging into the IAS infrastructure.

b) The Evaluation and Analysis subsystem will provide “generic” image processing applications (i.e., not unique to Landsat-7) as well as the capability to display and edit IAS system inputs, intermediate files, and outputs.

c) Landsat-7 unique applications for radiometric or geometric assessment and evaluation will be provided by the associated subsystem. IAS shall provide a mechanism for executing these applications.

d) Standard radiometric and geometric processing strings executed using the Work Order mechanism can be suspended for user intervention using IAS-defined mechanisms.

e) Radiometric algorithms operate on one band of image data at a time. No algorithms require multi-band or multi-image input.

2.3 IAS Design Constraints

A design constraint is defined as an external factor that limits system design options or mandates specific elements in the design. The IAS design is constrained by the following considerations:

1. The IAS shall be designed for maximum reuse by LPGS.

2. An SGI computer shall be used as the target processor for the IAS Operations System.

3. Oracle shall be used as the IAS RDBMS.

4. C shall be the primary programming language.

5. IDL shall be used to provide Evaluation and Analysis subsystem functionality, including at least part of the user interface.

6. COTS, NDI, and prototype products shall be used to the maximum extent possible in order to minimize schedule risk.

2.4 Open Issues

The following issues with potential impact to the IAS system design are still known to be open:

a) Definition and baselining of all radiometric and geometric algorithms to be accommodated within the IAS

b) Definition and baselining of the content and format of the Calibration Parameter File

c) Definition and baselining of the content and format of IAS reports

d) Definition of required IAS error handling capabilities, including identification of Level 1 and Calibration error conditions, associated level of severity, and action to be taken (automated or manual)

e) Definition of the MMO interface

f) Resolution of Level 0R Product searchable metadata fields available at the DAAC

g) Data retention and archival strategy

2.5 System Design Overview

The IAS system design derives from the analysis of the IAS system requirements and data flows contained in the documents listed in the Applicable Documents section (section 1.3), and the allocation of these requirements and functions to an IAS reference architecture.

The IAS reference architecture comprises two major components: the IAS functional flow architecture and the IAS interconnect architecture. The IAS functional flow architecture depicts the logical relationship among the IAS software subsystems. The

IAS interconnect architecture depicts the physical hardware architecture. These architectures are described below.

2.5.1 IAS Functional Flow Architecture

The IAS System Context Diagram is presented in Figure 2-1. This diagram shows the IAS in context with its external interfaces. The IAS Level 0 Data Flow Diagram, Figure 2-2, shows the IAS subsystems and their logical interfaces.

The IAS consists of the following subsystems.

a) Process Control Subsystem (PCS)

b) Data Management Subsystem (DMS)

c) Evaluation and Analysis Subsystem (E&A)

d) Radiometric Processing Subsystem (RPS)

e) Geometric Processing Subsystem (GPS)

A more complete description of the IAS subsystems shown in this architecture is provided in Section 3.

2.5.2 IAS Interconnect Architecture

The IAS interconnect or system block diagram, Figure 2-3, is based on the results of the IAS architecture trades and workload analysis studies. The architecture is described in detail in the next section.

2.6 IAS Hardware Design

This section presents the IAS hardware design. Section 2.6.1, "Hardware Configuration Items," lists and describes each Hardware Configuration Item (HWCI) and Hardware Component (HWC). Section 2.6.2, "Hardware Performance Analysis," explains how the hardware design satisfies IAS performance requirements.

2.6.1 IAS Hardware Requirements Allocation

Table 2-1 provides the allocation of IAS system requirements to hardware. The requirements are not presented in numerical order; rather, related requirements are grouped together. The complete mapping of IAS system requirements to IAS subsystems is provided in Appendix A.

Context-Diagram;1
Image Assessment System

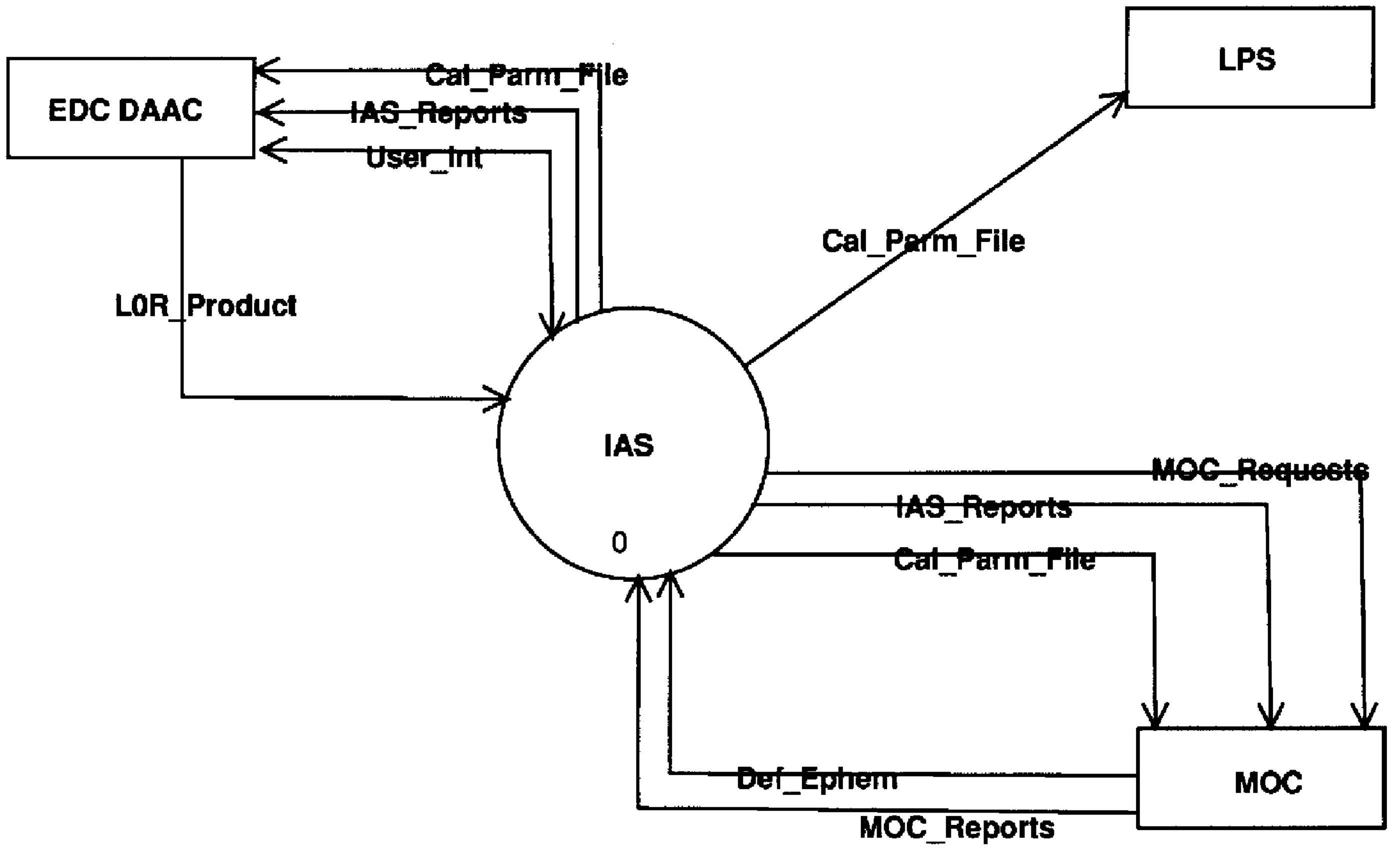


Figure 2-1. IAS System Context Diagram

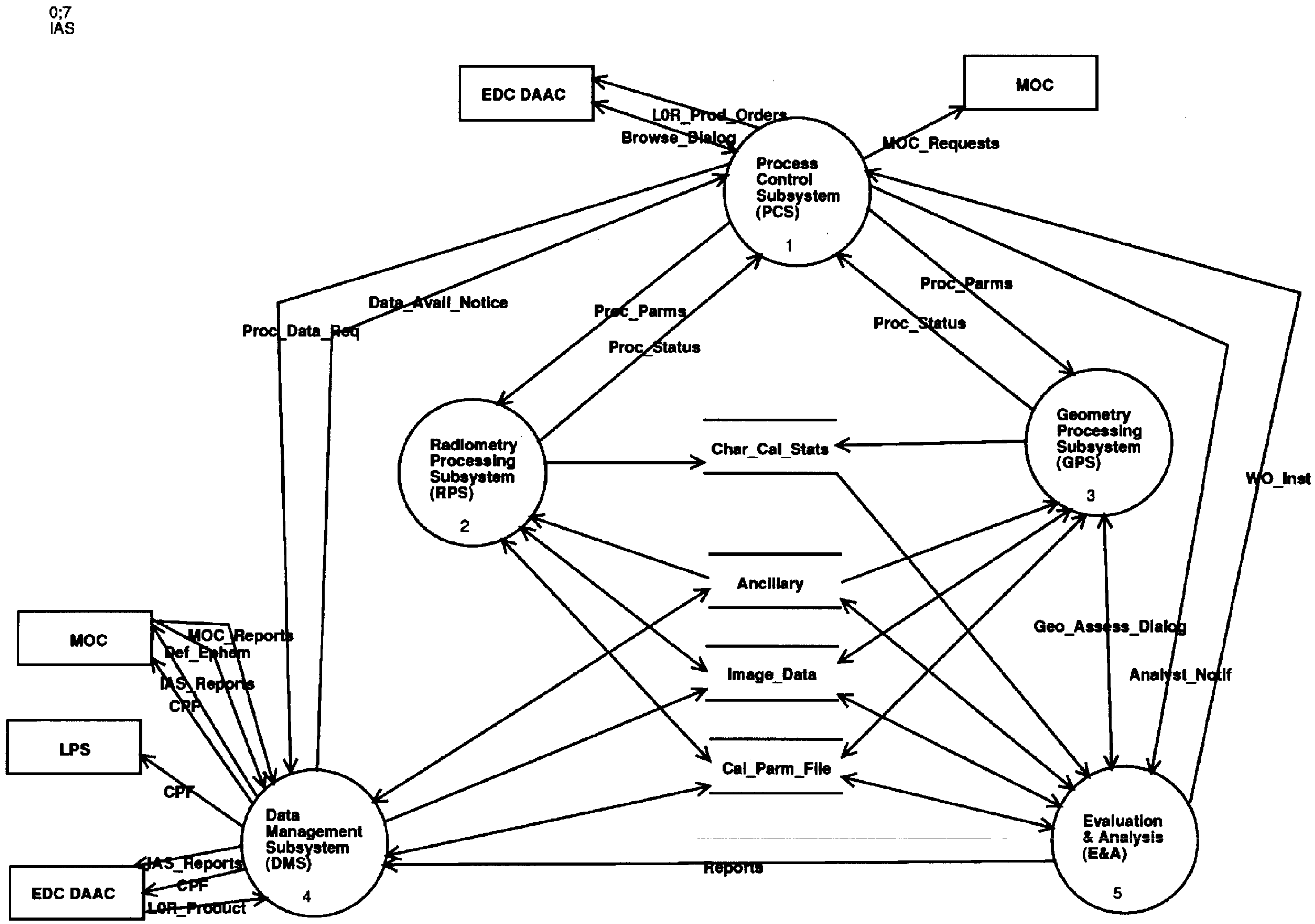


Figure 2-2. IAS Level 0 DFD

PROPOSED IAS ARCHITECTURE

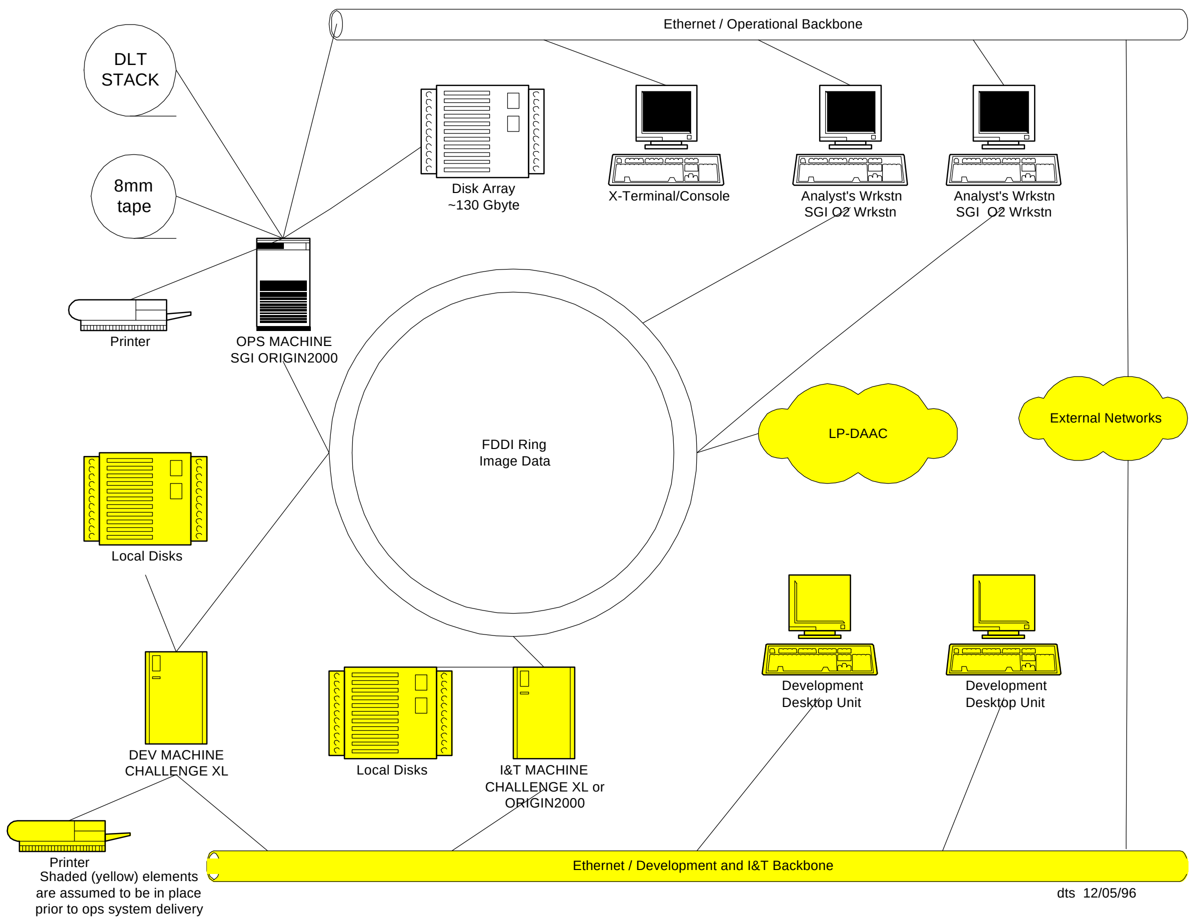


Figure 2-3. Proposed IAS Architecture

Table 2-1. Hardware Requirements Allocation

Reqt Number	Requirement Statement
3.2.3.14	The IAS shall be capable of generating the equivalent of up to 10 ETM+ Level 1G systematically corrected scenes in a 24-hour day over the life of the mission. (NOTE: This requirement is meant to size the maximum capacity of the system.)
3.2.3.15	The IAS shall be capable of receiving and storing 10 ETM+ Level 0R scene products or equivalent per day of data from the EDC DAAC.
3.2.3.20	The IAS shall have an on-line data storage capacity of 100 gigabytes (GB) (TBR) for image data.
3.2.3.22	The IAS shall capable of storing 20 GB of elevation data.
3.2.3.21	The IAS shall be capable of storing 68 megabytes (MB) of GCP data (points, chips, metadata).
3.2.2.6.10	The IAS shall have the capability to generate hardcopy outputs.
3.2.2.6.9	The IAS shall have the capability to write outputs to tape.
3.2.3.16	The IAS shall be capable of archiving test site image data (initial, intermediate, and final products), characterization data, calibration data, calibration parameter files, and reports, generated by the IAS, over the life of the mission.
3.2.2.5.1	The IAS shall have the capability to acquire, develop, test, and add new algorithms and software to improve the radiometric and geometric properties of ETM+ data and their assessment without impacting IAS operations.
3.2.2.5.2	The IAS shall support the development of algorithms to remove image artifacts and detector outages from Level 1R and 1G data without impacting normal IAS operations.
3.2.4.10	The IAS shall be capable of supporting training without impacting daily work loads.
3.2.4.11	The IAS shall provide an operational availability of 0.85 (TBR) or better for all processing functions.
3.2.4.12	The IAS shall support a mean-time-to-restore (MTTR) capability of 12 (TBR) hours or better.

2.6.2 IAS Hardware Configuration Items

Primary Operations System is a Silicon Graphics Challenge XL computer with x processors and y GB of RAM. This is the machine on which Level 1 and calibration processing operations are performed. Two x terminals are attached (operators consoles). RAID disks.

Two Image Analysts workstations. Silicon Graphics Indigo workstations. Used for data and image analysis.

Landsat-7 Integration and Test (I&T) System. SGI Challenge L server with x processors and y GB RAM. Shared with other Landsat-7 organizations at EDC for system I&T. Will have a complete configuration controlled copy of the IAS Operational System on it. Can be used as a backup machine when the Operations System is down.

Landsat-7 Development System. SGI Challenge L server with x processors and y GB RAM. Shared with other Landsat-7 organizations at EDC for system development and maintenance.

2.6.2.1 IAS Operations System HWCI

The IAS Operations System provides the computing and storage capabilities required for IAS Ingest, Level 1 processing, and Calibration processing. This HWCI consists of the following HWCs:

Silicon Graphics, Inc. (SGI) Origin2000 Server. The SGI Origin2000 servers are multi-processor systems designed for distributed computing environments. Their parallel architecture is based on a 1.6 GByte per second crossbar switch and interconnecting modules. This architecture can support up to 256 GBytes of RAM and 128 processors. The IAS Operations System will be initially configured with 2 processors and 2 Gbytes of RAM. Among the items included with the standard subsystem are an Ethernet controller, Versa Module European (VME/64) controller, SCSI controller, parallel ports, and serial ports.

IAS requires a multi-processor solution to satisfy its computational requirements, which are beyond the current capacity of a single processor.

X-terminals. The Operator Console HWC consists of 2 X-Terminals. These terminals are used by IAS Operators to monitor and control processing on the Operations System. The terminals are connected to the Origin2000 and Challenge L computers via the Ethernet LAN.

Attached Storage. The attached on-line and off-line storage will consist of the following items: a 4 Gbyte SCSI system disk, a 9 Gbyte SCSI swap disk, 130 Gbytes of disk storage connected via an Ultra-SCSI controller, an 8mm tape drive for backup ingestion of image data, and a DLT tape stacker for image data archival.

FDDI Network Controller Card. The IAS Operations System will be connected to the image data network via a FDDI interface card.

Ultra-SCSI Controller Card. The primary on-line storage devices will be connected to the Operations System through an Ultra-SCSI controller. The rated throughput of the Ultra-SCSI controller is 40 Mbytes per second. Other SCSI devices will be connected via built-in SCSI-2 interfaces.

2.6.2.2 Image Analyst Workstation HWCI

The Image Analyst Workstation HWCI consists of SGI Indigo workstations. These workstations are used by the IAS Analysts to perform data and image analysis, anomaly investigation, and report generation activities.

These workstations will be connected to the IAS computers via the FDDI LAN. A secondary Ethernet LAN connection may be implemented if deemed necessary. Display resolution will be 1280x1024. These workstations will have 2 4 Gbyte disks and 512 Mbytes of RAM.

2.6.2.3 IAS Network

FDDI HWCI. The image data FDDI network will be a dual-attached FDDI ring connecting the Operations System, the I&T System, the Development System, the Analyst's workstations, and the LP-DAAC. The transfer rate of this network is approximately 10 Mbytes per second.

Ethernet #1. The Operational Backbone network will be a IEEE 802.3 network providing for administrative traffic among the operational elements and providing access to the external networks. The transfer rate of this network is approximately 1 Mbyte per second.

Ethernet #2 The Development / Integration and Test Backbone network will be a IEEE 802.3 network providing for administrative traffic among the development and I&T elements and providing access to the external networks. The transfer rate of this network is approximately 1 Mbyte per second.

2.6.2.4 Landsat-7 Integration and Test System

The Landsat-7 IAS Integration & Test (I&T) System is currently slated to be a SGI Challenge XL shared by all of the Landsat-7 Projects at EDC. As it will be primarily used as an I&T machine and secondarily as a backup to the Operations System, commonality with the Operations System is of great importance. As the Operations Systems is likely to be implemented on a SGI Origin2000 system, this must be a consideration for the I&T System. The I&T System will have a copy of the current IAS operational software installed on it for use in a backup role. The I&T System's normal complement of peripherals will not support full operations and therefore the operational on-line storage devices will have to be relocated to the I&T Systems for contingency processing. This implies a requirement for an Ultra-SCSI controller card to attach the primary on-line storage devices. The I&T System will always be attached to the image data FDDI network and to the Development Backbone network.

2.6.2.5 Landsat-7 Development System

The Landsat-7 IAS Development System is a Challenge XL shared by all of the Landsat-7 Projects at EDC. It is used for software development and maintenance. The Development System may have a copy of the IAS operational software installed on it, but it will not be relied upon as a backup system. The Development System does not have any extensive on-line storage attached directly. It is to connected to the image data FDDI network and the Development Backbone network.

2.6.3 Hardware Performance Analysis

The analysis focuses on two areas of concern: CPU floating point performance and primary storage I/O performance. The analysis will demonstrate that the proposed architecture will meet the processing requirements for the IAS.

Information regarding the processor load was supplied by the EDC personnel based on the loading requirements of similar missions with similar processing. This information was complied into a format whereby it could be referenced on a per scene basis. The IAS is required to process 10 scenes per day. Additionally, there must be an allowance for the analysts to make processing adjustments within a scene.

The initial estimates for processing were 100 giga-flops (GFLOPS) per scene and 18 Gbytes of I/O processing per scene. It was determined later that the I/O processing could be reduced to 11.2 Gbytes by eliminating the interim disk accesses during the processing.

The IAS computer will have 2 R10000 processors, each rated at roughly 425MFLOPS. Allowing for considerable process overlap, an aggregate processing rate of 0.7 GFLOPS per second can be expected. The floating point processing for a worst case scene will be completed in roughly 170 seconds. The I/O processing is constrained by the data transfer rate of the disk subsystem. This is approximately 30 Mbytes per second. At 11.2 Gbytes of I/O per scene, the I/O processing time of the scene will be 7 minutes.

As the analysis shows, the specified IAS computer exceeds the requirement for the IAS processing and will allow for a great deal of analyst intervention without schedule impact.

The MTBF and MTTR of the Challenge XL computer as configured are 10,578 hours and TBS, respectively.

Table 2-1 provides the allocation of IAS system requirements to hardware. The requirements are not presented in numerical order; rather, related requirements are grouped together. The complete mapping of IAS system requirements to IAS subsystems is provided in Appendix A.

2.7 Software Configuration Items

An overview of the IAS software architecture is presented in this section. The architecture incorporates both custom IAS applications and COTS or NDI system and support applications to meet its functional and performance requirements.

2.7.1 Software Considerations

The following considerations were taken into account in developing the IAS software architecture:

a) The IAS software architecture must fulfill IAS software functional requirements in general and performance requirements in particular.

b) The architecture should be designed so as to minimize IAS software development time. This drives the design to incorporate to the maximum extent possible COTS products or to reuse applications from previous missions. As a result, several COTS products, including Oracle, IDL, and ENVI, have been incorporated into the design. The specific application of these products in satisfying IAS requirements is presented briefly in Section 2.7.3 and in more detail in Section 4. In addition, potential sources of software for reuse are being identified and analyzed. Candidate systems at GSFC and EDC include LAS, Pacor II, DDF, and LPS. Further, reuse of existing radiometry and geometry prototypes is planned to the maximum extent possible.

c) The architecture should be designed for maximum reuse by LPGS. This requires that special attention be paid to software performance. To that end, opportunities for applying parallel programming to IAS will be identified and investigated. The detailed design will seek to take advantage of multiprocessors provided by SGI, parallelizing code which normally runs in serial mode to optimally spread the same work over several processes running on different Central Processing Units (CPUs) within the SGI Challenge XL.

2.7.2 IAS Application Software

The IAS application software configuration items correspond to the subsystems identified in section 2.5 and depicted in Figure 2-2. The following paragraphs describe the purpose and basic functionality of each subsystem. A more detailed description of each subsystem is presented in Section 3.

a) Process Control Subsystem (PCS)

The Process Control Subsystem provides the tools needed by the IAS Operator to plan and manage the processing being performed by the IAS. PCS applications are used by the Operator to browse EDC DAAC holdings and order data for ingest, or to make calibration scheduling requests to the Mission Operations Center. PCS provides the Operator with the capability to establish Work Orders specifying the processing to be performed on the data ingested by the IAS and to set priorities for Work Order execution.

PCS also controls the execution of Radiometric and Geometric Processing Subsystem applications by initiating and managing Work Order processing.

b) Data Management Subsystem (DMS)

The Data Management Subsystem manages the data formatting and transfer interfaces with external systems. It performs ftp functions during data ingest, stores the data in the appropriate internal data stores, and updates data availability information. For data export, DMS performs the appropriate data formatting and supports the ftp transmission of these data to external systems.

DMS also performs quality checking and correction of the Level 0R Products. This function is performed once upon receipt of the product from the EDC DAAC. During Work Order startup, DMS also performs a data preparation function, extracting the requested subset of data from the PCD, and possibly the MSCD and image files.

c) Evaluation and Analysis Subsystem (E&A)

The E&A Subsystem supports the IAS Analyst in evaluating and analyzing the performance of the ETM+ instrument and in maintaining the Calibration Parameter File. To accomplish this, E&A provides: a GUI to other applications; utilities to view radiometric and geometric processing inputs, intermediate products, and results; “generic” image processing applications for image analysis and statistical analysis; and file edit and Work Order Setup applications for performing “what if” analyses.

d) Radiometric Processing Subsystem (RPS)

The Radiometric Processing Subsystem provides all functionality required for Level 1R product generation, radiometric calibration, and radiometric characterization and evaluation. This subsystem implements all of the IAS radiometry algorithms.

e) Geometric Processing Subsystem (GPS)

The Geometric Processing Subsystem provides all functionality required for Level 1G product generation, geometric calibration, and geometric characterization and evaluation. This subsystem implements all of the IAS geometry algorithms.

2.7.3 IAS Support Software

The IAS support software consists of COTS system and application software components that either satisfy IAS requirements directly or that are needed by the IAS application software. Specific applications incorporated into the design are listed below and described in more detail in Section 4.

IAS system Software Configuration Items (SWCIs) incorporated into the IAS design include:

a) IRIX 6.2 operating system

b) FDDI Device Interface

c) TCP/IP software

d) device drivers for system peripherals

COTS support application SWCIs incorporated into the IAS design include:

a) Oracle Database Management System (DBMS). Oracle is adopted as a vehicle for generating and storing Work Orders and collecting and monitoring Work Order execution information. Oracle’s Structured Query Language (SQL) and SQL*Forms are used to manage and manipulate the information. In addition, the IAS radiometry and geometry applications use database calls to store characterization, correction, and calibration results and statistics and associate them with specific scenes or detectors.

b) Oracle's SQL*Forms and X/Motif GUI Tools. To simplify the user interface application, the IAS presents the IAS Operator with a simple and well-defined menu structure for controlling its operations. The User Interface (UI) is based on X/Motif and Oracle's SQL*Forms. X/Motif has achieved wide acceptance and is in use at the EDC site. It provides the basis for a consistent look and feel across multiple EDC systems. The UI provides a framework within which a menu system is built. The UI is decoupled from the IAS applications themselves. It functions as a stand alone component, receiving input from the users and passing this input to the applications, enabling the display area for output from the applications to be managed.

c) National Center for Supercomputer Applications (NCSA) Hierarchical Data Format (HDF) tools. HDF tools are used for manipulating the HDF-formatted Level 0R Product ingested from the DAAC and for formatting IAS-generated products for transmission to the DAAC. The tools are also used for manipulating HDF-formatted internal datasets

d) Interactive Data Language (IDL). The IAS Analyst interface will be built using IDL. IDL's command line interpreter and other applications will be used to satisfy E&A subsystem requirements for image analysis and manipulation. IDL has achieved wide acceptance in the science community at EDC and is being used by EDC in the development of IAS prototype applications.

e) Environment for Visualizing Imagery (ENVI). ENVI provides general purpose image processing applications that satisfy many of the E&A subsystem's requirements. ENVI is built on IDL.

f) Commercial Web Browser. A Web Browser is needed to attach to the EDC DAAC and its search and ordering applications.

g) COTS software development environment. The IAS development environment includes an ANSI-compliant C compiler, a debugger, and a *Power C Analyzer (PCA*) from SGI. The PCA will be used to analyze the opportunities for parallel programming. In addition, *Purify* and possibly other tools will be used to validate source code and to analyze memory leak problems. IAS software configuration management will be accomplished using PVCS.

Non-Development Item (NDI) support application SWCIs incorporated into the IAS design include the following EOSDIS Core System (ECS) applications:

a) Earth Science Search Tool (ESST). ESST is used to browse DAAC holdings.

b) Product Request Tool (PRT). PRT is used to place orders for DAAC products.

c) ECS Ingest GUI. This tool is used to generate an ECS network ingest request form, required for transmitting IAS products to the ECS.

d) EOS-HDF Toolkit. This toolkit is used to format ECS inputs into an internal EOS HDF format.

It is not clear whether the ESST, PRT, and ECS Ingest GUI execute on the IAS Operations System or on EDC DAAC servers.

2.8 Integration and Test (I&T) Strategy for IAS

This section presents the roles and responsibilities of the development and test organizations as they relate to the buildup, integration and testing of the IAS system.

There are three development organizations - one each for the IAS infrastructure, Radiometric Processing Subsystem, and Geometric Processing Subsystem - and the IAS Test Team. The development team for the Geometric Processing Subsystem is located at the EROS Data Center in Sioux Falls, SD; the other development teams and the IAS Test Team are located at the Goddard Space Flight Center in Greenbelt, MD.

The specific types of tests planned for IAS and the responsibilities of each organizations related to these tests is presented in Table 2-2.

Table 2-2. Planned Tests and Organizational Responsibilities

Test Phase	Test Objective	Performed By
Test Planning	Develop a detail test plan which details the methods and resource that will be used in testing.	Test Lead
Unit Test	Verify Path Coverage and unit functionality.	Unit Developer
Module Test	Integrate unit into modules and verify interface within modules.	Development Organization
Module Integration Test	Integrate modules into functional subsystem to test interface between subsystems.	Development Organization
Build Integration	Integrate subsystem to test External Interfaces.	Development Organization
Integration Test	Verify interfaces between subsystems	Test & Development Organization
System Test	Same as Acceptance Test with emphasis on compliance with requirements.	Independent Test Organization
Acceptance Test	Verify ability to fulfill the operational need, compliance with requirements, functionality of entire system, ability to support erroneous data, and ability to support external interfaces. Emphasis on ability to fulfill the operational need.	Operations Organization
Mission Readiness Test	Verify that the system is ready to meets its requirement in a operational context	Operations Organization
Operation	Verify a collection of activities performed using hardware, software, and human action to meet mission requirements at major milestones of the mission	Operations Organization

Testing through Build Integration is the responsibility of the development organizations The test team will support each of the development groups they concurrently develop their parts of the IAS. In light of schedule pressures, the Test Team will likely support the AIT during Build Integration. Similar support is available to EDC in order that the Test Team might influence Build Integration Testing and decrease Integration Test risks.

This approach has the following advantages:

- Promotes sharing of test data, test tools, and test experience between development and test groups

- Provides the Test Team with the opportunity to gain early experience with the system, reducing the learning curve that typically occurs at the start of system testing

- Ensures the development organization meets its responsibility to assure that their software is functional before turning it over to the independent test organization

- Reduces cost since the development organization typically uses less formal configuration control than the independent test organization and can therefore fix problems more quickly and cheaply

The successful completion of the System Test phase will allow the software to pass to the Site Installation and Acceptance Test phase. Following installation of the system at EDC, EDC personnel will conduct acceptance tests to demonstrate that the system meets each requirement and is ready to support mission readiness test phase.

Section 3. System Design

This section provides a detailed description of the IAS subsystems. For each subsystem, the allocated IAS system and derived requirements, interfaces, primary functions, major data items, hardware and software are described.

3.1 Process Control Subsystem (PCS)

The Process Control Subsystem provides capabilities for planning, monitoring, and controlling the Level 1, Calibration, and Evaluation and Assessment processing performed on the IAS Operations System. It is used by the Operator when interacting with external systems to order input data products or to schedule data acquisitions. It permits the Operator to set up Work Orders (WOs) specifying the processing to be performed on the data, to prioritize the processing to be performed, and to monitor the status of Work Order execution. It also performs automated Work Order execution by monitoring required and available system resources, initiating application processing, and monitoring application execution status.

3.1.1 Requirements Allocation

Table 3-1 provides the allocation of IAS system requirements to the Process Control Subsystem. The requirements are not presented in numerical order; rather, related requirements are grouped together. The complete mapping of IAS system requirements to IAS subsystems is provided in Appendix A.

Table 3-1. Process Control Subsystem Requirements Allocation

Number	Requirement Statement
3.2.1.1.1	The IAS shall interface with the EDC DAAC for purposes of searching for and ordering of data from the Landsat 7 archive.
3.2.4.13	The IAS shall be capable of retrieving cross-calibration data of other sensors from the EDC DAAC.
3.2.1.3.1	The IAS shall send requests to the MOC for the operational acquisition of partial-aperture calibration data, full-aperture calibration data, and surface image data of radiometric and geometric calibration ground sites.
3.2.1.3.3	The IAS shall send requests to the MOC for concentrated definitive ephemeris.
3.2.2.6.1	The IAS shall provide the capability to select the processing to be applied to data sets.
3.2.2.6.12	The IAS shall allow the operator to select thresholds for results and errors reported by the IAS.
3.2.2.6.4	The IAS shall have the ability to monitor and control processes.
3.2.2.6.13	The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.
3.2.2.7.5	The IAS shall generate processing summaries after each IAS activity.
3.2.2.6.10	The IAS shall have the capability to generate hardcopy outputs.
3.2.2.5.1	The IAS shall have the capability to acquire, develop, test, and add new algorithms and software to improve the radiometric and geometric properties of ETM+ data and

	their assessment without impacting IAS operations.
3.2.2.5.3	The IAS shall have the capability to incorporate new algorithms into the operational system without impacting normal IAS operations.

3.1.2 Derived Requirements

Table 3-2 presents the derived requirements for the Process Control Subsystem.

Table 3-2. Process Control Subsystem Derived Requirements

Number	Requirement Statement
PCS-1	The user shall be able to interactively enter or update a Work Order specifying the processing to be performed.
PCS-2	Both standard batch and "what if" processing shall be accommodated. The IAS shall segregate data generated during "what if" processing from that generated during standard batch processing.
PCS-3	The IAS shall allow the Operator to assign priorities to Work Orders and shall execute the Work Orders in priority sequence.
PCS-4	The IAS shall provide the capability to generate and modify procedures specifying processing to be performed.
PCS-5	The IAS shall have the capability to pause the execution of a Work Order at predefined points and to continue the processing of a Work Order on user command.
PCS-6	The IAS shall maintain the status of all Work Orders.
PCS-7	The information associated with a work order shall be kept for the life of the mission.
PCS-8	The information maintained with each work order shall include (but is not limited to) the following: a) unique work order id b) date/time work order entered c) name of requester d) type of request (e.g. standard, custom, test, etc.) e) image input file(s) f) date/time input file(s) requested g) date/time input file(s) received h) processing procedure to be performed on each file I) status of each processing step performed j) action to take prior to starting next step (e.g. pause for analysis) k) desired completion date l) date/time of completion of work order m) current status of work order (e.g. in progress, complete, withdrawn, etc.) n) work order priority

3.1.3 Interfaces

The Process Control Subsystem context diagram, Figure 3-1, shows PCS interfaces to other IAS subsystems and to other systems external to IAS.

The IAS users interact with each of the Process Control functions through a User Interface (UI).

PCS interfaces with the DAAC via ESDIS Project-supplied utilities that allow the Operator to browse available L0R products and to place orders for their transmission to IAS.

PCS interfaces with the MOC via TCP/IP to transmit requests for scheduling ETM+ instrument calibration operations and for concentrated ephemeris needed for geometric calibration activities.

The Data Management Subsystem updates data availability information when data from the DAAC or MOC have been ingested and quality checked and are available for processing. PCS then initiates the appropriate processing of these data.

PCS sends several types of requests for processing to DMS. When Work Order execution begins, PCS activates DMS to extract (subset) the PCD and possibly image data as specified in the Processing Parameters for the Work Order. When Work Order execution has completed, PCS activates DMS to "clean up" datasets associated with the Work Order execution. PCS also activates DMS to move data between the on-line data stores and the off-line archive, and to generate, format, and transmit IAS products (reports or the Calibration Parameter File) to external interfacing systems.

PCS controls the processing performed by the Radiometric and Geometric Processing Subsystems during Work Order execution. PCS passes processing parameters specifying input files and user-selected options to these application subsystems and receives application processing status in return.

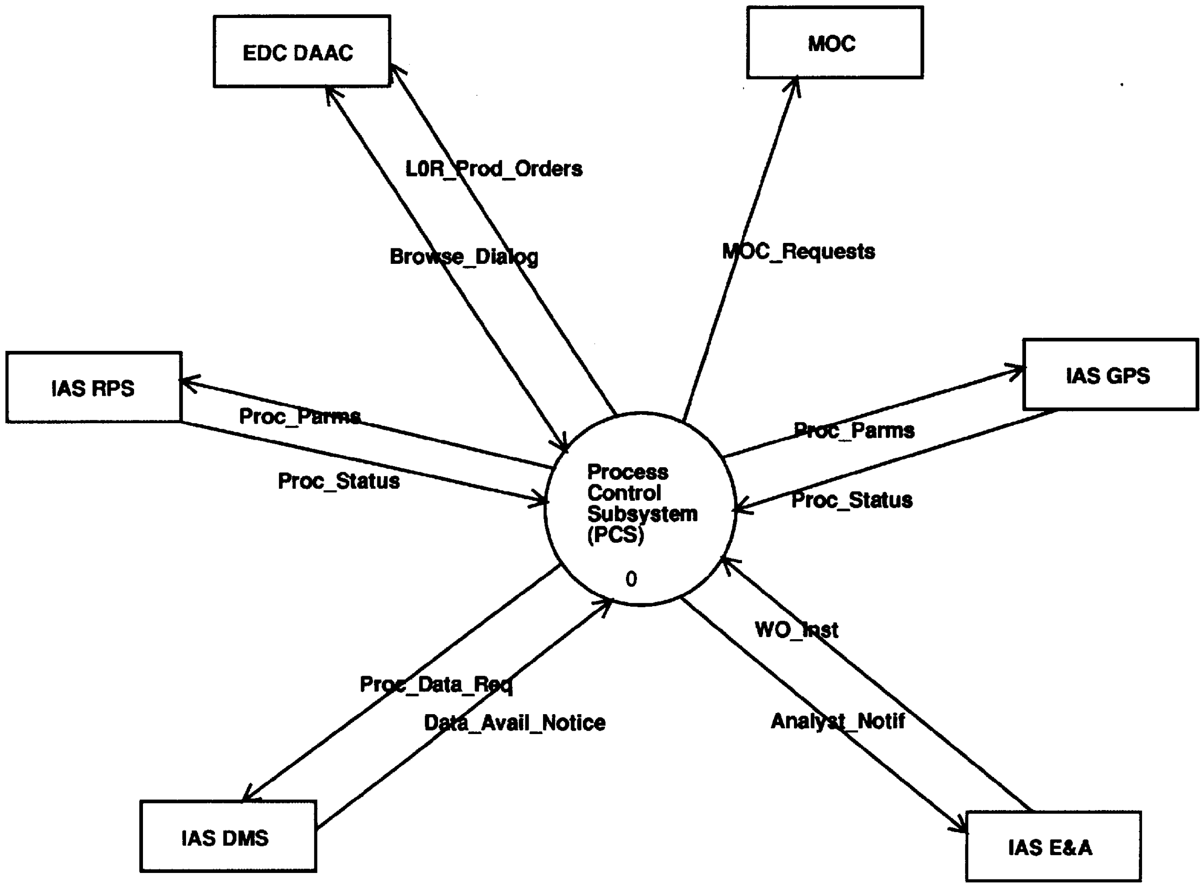


Figure 3-1. PCS Context Diagram

PCS interacts with the Evaluation and Analysis subsystem to notify IAS Analysts when Work Orders have completed execution and processing results are ready for review. PCS also receives Work Order instructions from E&A that cause paused Work Orders to be resumed or to enter new Work Orders for "what if" analyses.

3.1.4 Functional Description

Figure 3-2 presents the PCS Level 0 data flow diagram depicting the subsystem's primary functions. Those functions are described in the following sections.

3.1.4.1 Order Images

The Order Images function supports the IAS Operator in browsing EDC DAAC holdings to identify and order Level 0R products of interest for processing by IAS. The ability to browse EDC DAAC holdings by searching Level 0R product metadata or by visually inspecting associated "browse images" and to subsequently order the L0R Product will be accomplished using a Web browser.

3.1.4.2 Generate Work Order

The Generate Work Order function provides the IAS user (Operator or Analyst) with the capability to complete a Work Order specifying the parameters to be used in performing radiometric and geometric processing on the IAS Operations System. This is accomplished by filling in a Work Order form or by modifying an existing WO using the IAS Operations UI. Default values will appear in Work Order form fields where appropriate.

The Generate Work Order function allows the user to generate WOs for future processing prior to selecting specific input image files. At a minimum, the user must specify the type of image to be processed by the Work Order; the user can also specify required completion dates for the Work Orders. The remaining WO fields - for example the names of the input image files - can be specified when the files are ordered from the DAAC. This capability allows a user to generate, at one sitting, Work Orders for all of the processing required to meet quarterly assessment, evaluation, and reporting requirements. When a user finally does specify the image files to be used as input in processing the WO, the system will check to see if the file is already on-line. If a match is found, the user will be prompted to either accept the file that is currently on-line or to order the data from the DAAC (e.g., in the case where a newer version may exist in the DAAC).

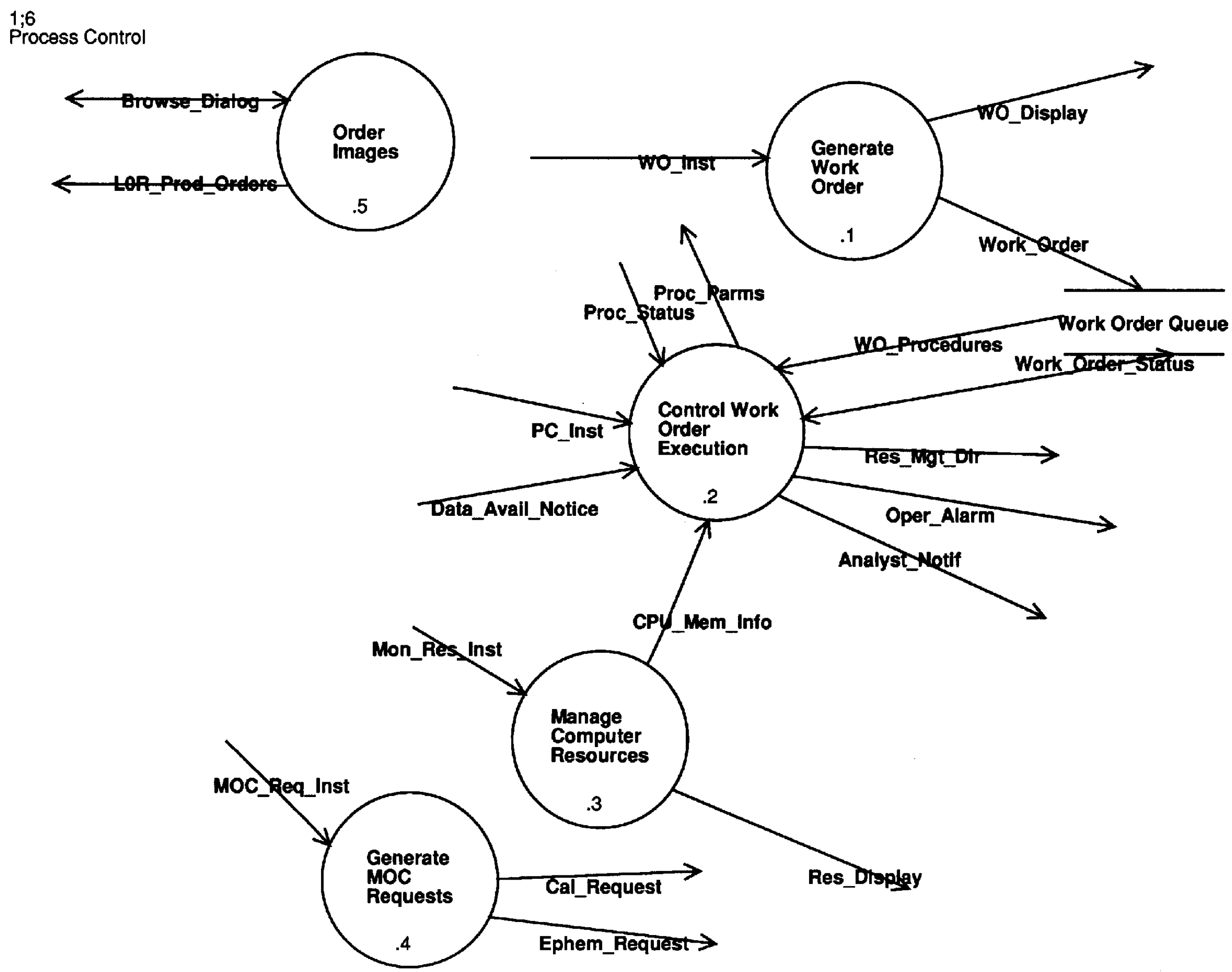


Figure 3-2. PCS Level 0 Data Flow Diagram

The Generate Work Order function also allows the user to display any or all of the WOs entered into the system along with their status. These queries can be used to review WOs submitted by a specific user or to identify all of the WOs due in a particular time period. This can serve the user as a reminder of data acquisitions to be scheduled and/or data products to be ordered.

3.1.4.3 Control Work Order Execution

The Control Work Order Execution function is used to initiate, monitor, and control WO execution.

Several Operator control and monitoring capabilities are provided. First, the Operator can manually initiate processing of a WO and can assign the WO an execution priority. Priorities will be based on userid and processing urgency ("normal" and anomaly) and can be changed by the Operator. Second, the Operator can display the current status of executing WOs. The status information shall indicate the currently executing procedure step as well as status and error messages from previous processing steps. Third, the Operator will be notified via an alarm mechanism of error conditions requiring intervention. The Operator may then elect to modify or terminate the associated Work Orders.

The Control Work Order Execution function can also initiate Work Order processing automatically. The function identifies Work Orders that are candidates for execution by periodically monitoring the Work Order Queue for WOs for which all required input data are marked as available. Level 0R Products that are received for which there is no corresponding Work Order will cause an alarm to be generated for operator attention. When all required inputs are available, the system resources are allocated, and processing begins.

A Work Order is linked to a procedure that defines the processing to be performed. A procedure is composed of one or more shell scripts. These scripts identify the IAS applications to be executed in sequence along with the required input parameters, files, and system resources. They also identify points at which processing is to be suspended for manual intervention.

Standard procedures will be generated pre-launch that specify the standard sequence of radiometric and geometric applications to be executed for each IAS image file type. These procedures will be placed under configuration control. The standard sequences are defined in Section 5.

As WO execution proceeds, processing status is returned by the called applications. A complete history is maintained for the WO of the processing steps executed, the parameters applied, and the status returned. Status is checked following the completion of each script. Alarms are generated, if necessary, and processing is suspended, if necessary. If a WO requires manual intervention at some point in processing then the Control Work Order Execution function will issue an alert and hold the WO until the required manual intervention has been completed and acknowledged.

3.1.4.4 Manage Computer Resources

The Manage Computer Resources function is responsible for the allocation of CPU and memory resources when a resource request is received from the Control Work Order Execution function. The Manage Computer Resources function provides the IAS user with tools for monitoring CPU and memory allocations and availability across IAS.

3.1.4.5 Generate MOC Requests

The Generate MOC Requests function is responsible for creating and transmitting requests for services to the MOC. These include requests for scheduling ETM+ calibration operations and requests for concentrated definitive ephemeris (which the MOC forwards to the Flight Dynamics Facility). The required format of these requests is documented in the *Landsat 7 Mission Operations Center (MOC) to Image Assessment System (IAS) Interface Control Document (ICD).*

3.1.5 Data

This section defines the data flows and data stores appearing in Figure 3-2.

Analyst_Notif (data flow) = Analyst Notification. Automated notification of the IAS Analyst that processing results are available for review.

Browse_Dialog (data flow) = Browse Dialog. The dialogue - operator commands and system responses - that occurs when the IAS operator browses the Landsat-7 data holdings at the EDC DAAC.

CPU_Mem_Info (data flow) = CPU/Memory Information. Information regarding the utilization and allocation of CPU and memory resources of the system.

Data_Avail_Notice (data flow) = Data Availability Notice. Notifies the recipient of the availability of data for processing..

Ephem_Request (data flow) = Ephemeris Request. Request for transmission of Concentrated Ephemeris data..

L0R_Prod_Orders (data flow) = L0R Product Orders. Orders placed by the IAS Operator with the DAAC for Level 0R Products.

MOC_Req_Inst (data flow) = MOC Request Instructions. Instructions issued by the Operator requesting services from the Mission Operations Center.

Mon_Res_Inst (data flow) = Monitor Resource Instructions. Instructions issued by the operator to the system to monitor system resource utilization .

Oper_Alarm (data flow) = Operator Alarm. Audible or visual alarm generated on the Operator's console

PC_Inst (data flow) = Process Control Instructions. Instructions issued by the IAS Operator to initiate, suspend, terminate, or change priority of an IAS process.

Proc_Parms (data flow) = Processing parameters. Parameters specified to control IAS application processing.

Proc_Status (data flow) = Processing Status. Processing execution status returned by an IAS application..

Res_Display (data flow) = Resources Display. Display of CPU and memory utilization and allocations.

Res_Mgt_Dir (data flow) = Resources Management Directive. Operator directives for system resource allocations.

WO_Display (data flow) = Work Order Display. Display of Work Order contents for review by operator or analyst.

WO_Inst (data flow) = Work Order Instructions. Instructions issued by an IAS Operator or Analyst specifying Work Order parameters or control directives.

WO_Procedures (data flow) = Work Order Procedures. Procedures to be executed as part of Work Order processing.

Work_Order (data flow) = Work Order. Procedures and associated user-input parameters specifying specific IAS applications to be executed.

Work_Order_Status (data flow) = Work Order Status. Execution status of a particular Work Order.

WorkOrderQueue (store) = WorkOrderQueue. Queue of Work Orders submitted for execution by IAS.

3.1.6 System/COTS Software

The PCS will make extensive use of COTS, NDI, and system software.

Oracle will be used for storing Work Order data. Operating system and possibly COTS software will be used to control the execution of the WOs and for monitoring and reporting on system resource usage. The PCS UI will utilize system-supplied X libraries, Oracle Forms, or a COTS GUI builder.

A commercial Web browser will be used to search EDC DAAC holdings for Level 0R products of interest. Other NDI products are used in data search and ordering. These are the Earth Science Search Tool (ESST) and Product Request Tool (PRT) developed by Hughes Information Technology Corporation under the EOSDIS Core System (ECS) contract. It is unclear whether ESST and PRT clients will be executing on the IAS Operations System or remotely on the EDC DAAC servers.

3.1.7 Subsystem Hardware

The PCS executes in the IAS Operations System. No special purpose hardware is required.

3.2 Data Management Subsystem (DMS)

The Data Management Subsystem (DMS) provides the functions required to ingest, archive, and distribute the IAS data. These data consists of image data, ancillary data, characterization and calibration results, and reports.

3.2.1 Requirements Allocation

Table 3-3 provides the allocation of IAS system requirements to DMS. The requirements are not presented in numerical order; rather, related requirements are grouped together. The complete mapping of IAS system requirements to IAS subsystems is provided in Appendix A.

Table 3-3. Data Management Subsystem Requirements Allocation

Number	Requirement Statement
3.2.1.1.2	The IAS shall receive Level 0R data, Level 0R products, and associated ancillary data from the EDC DAAC.
3.2.3.15	The IAS shall be capable of receiving and storing 10 ETM+ Level 0R scene products or equivalent per day of data from the EDC DAAC.
3.2.1.3.6	The IAS shall be capable of receiving telemetry trend reports, spacecraft status reports, and event schedules from the MOC.
3.2.1.3.7	The IAS shall be capable of receiving Flight Dynamics Facility (FDF)-generated, definitive ephemeris from the MOC.
3.2.3.18	The IAS shall provide regular calibration and performance updates to the EDC DAAC and other interfaces quarterly.
3.2.1.1.4	The IAS shall send calibration parameter files and IAS-generated reports to the EDC DAAC.
3.2.2.7.2	The IAS shall be capable of generating metadata for all reports sent to the EDC DAAC Guide Server.
3.2.1.2.4	The IAS shall send calibration parameter files to the LPS.
3.2.1.3.5	The IAS shall send calibration parameter files to the MOC.
3.2.1.3.4	The IAS shall send problem reports to the MOC.

3.2.2.4.12	The IAS shall be able to evaluate the quality of Level 0R products. Quality checks will include but not be limited to those listed in Table 3.2.2.4-1. Specific checks include validating: - Ranges of all but the housekeeping parameters in the L0R Product Payload Correction Data - Scan direction consistency in the L0R Product Mirror Scan Correction Data - FHSERR/SHSERR consistency in the L0R Product Mirror Scan Correction Data - Counted line length consistency in the L0R Product Mirror Scan Correction Data - Consistency of the applicability date in the Calibration Parameter File with the L0R Product image files - Consistency of the Calibration Parameter File of the L0R Product with the IAS database - Scene coordinates from the L0R Product metadata - File name consistency from the L0R Product metadata - Correctness of WRS scene parameters from the L0R Product metadata
3.2.4.8	The IAS shall perform calibrations, assessments, and evaluations with frequencies specified in Tables 3.2.4-1 and 3.2.4-2. These include: - Evaluation of LPS data quality - Evaluation of Level 0R data and products - Evaluation of PCD quality
3.2.2.3.1	The IAS shall be capable of processing payload correction data (PCD) data to correct spacecraft time, generate a sensor pointing model (attitude and jitter), and calculate spacecraft position and velocity (ephemeris).
3.2.2.6.13	The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.
3.2.2.7.1	The IAS shall generate calibration, data quality assessment, and problem reports.
3.2.2.7.5	The IAS shall generate processing summaries after each IAS activity.
3.2.3.20	The IAS shall have an on-line data storage capacity of 100 gigabytes (GB) (TBR) for image data.
3.2.2.6.3	The IAS shall be capable of storing selected data, parameters, ancillary data, reports, and documents.
3.2.3.16	The IAS shall be capable of archiving test site image data (initial, intermediate, and final products), characterization data, calibration data, calibration parameter files, and reports, generated by the IAS, over the life of the mission.
3.2.2.6.2	The IAS shall be capable of archiving all software and databases used in operations.
3.2.4.7	The IAS shall ensure backup of all on-line data and operations software.
3.2.2.6.9	The IAS shall have the capability to write outputs to tape.

3.2.2 Derived Requirements

Table 3-4 presents the derived requirements for the IAS Data Management Subsystem.

Table 3-4. Data Management Subsystem Derived Requirements

Number	Requirement Statement
DMS-1	DMS shall extract and store individual files from the Level 0R Product.
DMS-2	DMS shall maintain internal directories for storing intermediate products during Work Order processing.
DMS-3	DMS shall maintain a catalog of data received by IAS.
DMS-4	DMS shall handle communications for data interchange with external systems.
DMS-5	DMS shall extract Calibration Parameter fields from the IAS database and format the Calibration Parameter File for distribution to external systems.

3.2.3 Interfaces

The Data Management Subsystem context diagram, Figure 3-3, shows DMS interfaces to other IAS subsystems and to other systems external to IAS.

The MOC interface is provided through transmission of ASCII files using TCP/IP. Definitive Ephemeris files, used in geometric correction of the image data and in analysis of geometric correction performance, are received from the MOC weekly. Concentrated ephemeris files are received from (FDF via) the MOC upon request from IAS. Telemetry Trending Analysis Reports and Spacecraft Status Reports are received from the MOC in response to IAS requests for anomaly investigation support. The quarterly Spacecraft Status Report is also received.

The DMS sends the Calibration Parameter File to the MOC, the LPS and the EDC DAAC quarterly or whenever a change is detected sufficient to warrant generation of an updated Calibration Parameter File. DMS also formats Reports and Assessments for transmission to these destinations.

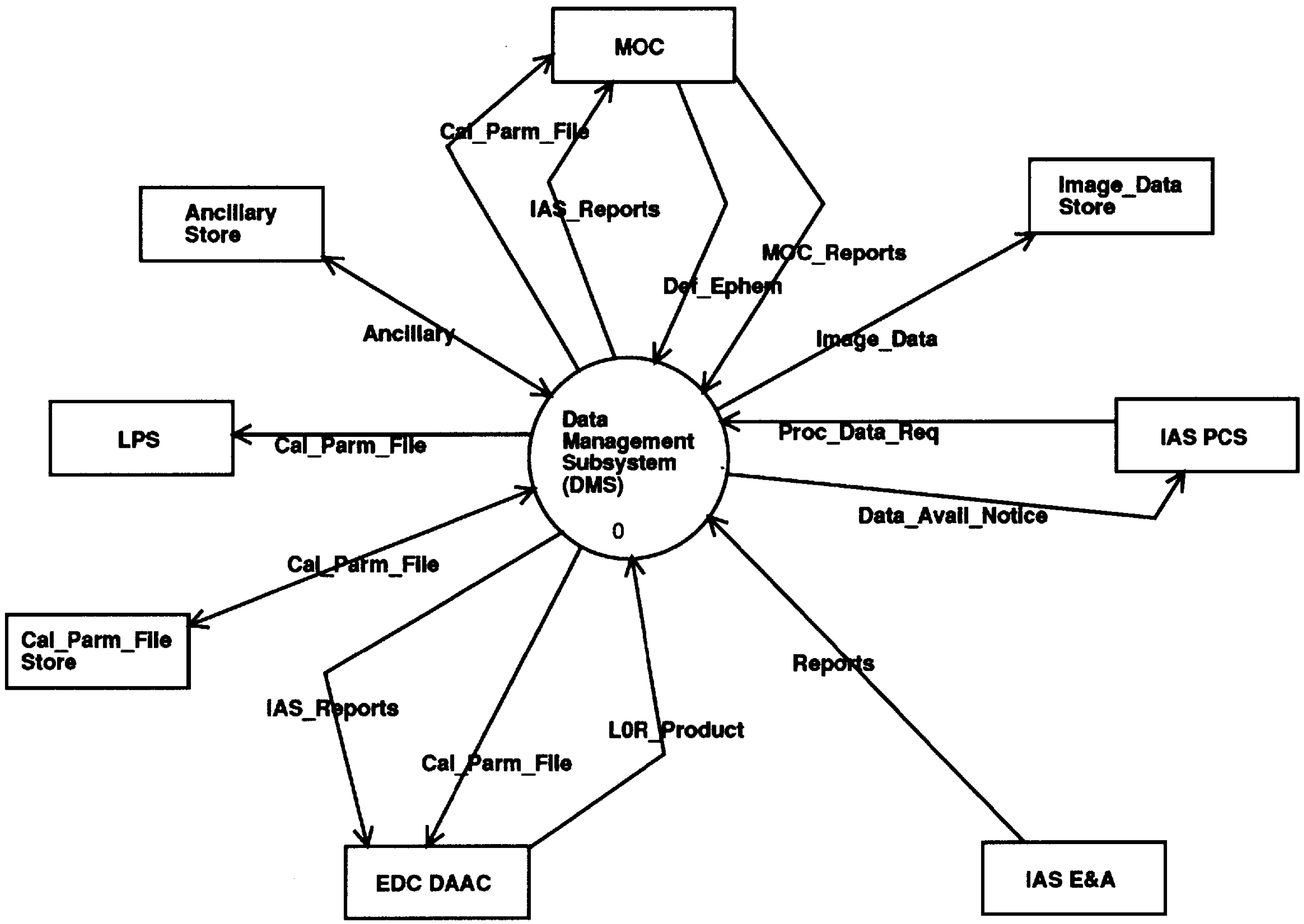


Figure 3-3. DMS Context Diagram

Level 0R Products are ingested from the EDC DAAC using TCP/IP. Data Availability Notices are received from the EDC DAAC indicating that an IAS-requested Level 0R Product has been staged at the DAAC for transfer. DMS retrieves the product from the DAAC, extracts and stores the individual files, and performs quality checks on the received files.

DMS updates data availability information notifying PCS that data have been received and quality checked and are available for processing. During Work Order startup, PCS instructs DMS to extract the desired data from the input files and to establish internal directories for storing intermediate products generated during Work Order execution. Upon completion of Work Order execution, PCS instructs DMS to clean up the intermediate files and delete the associated directories

DMS receives Reports and Assessments from E&A for transmission to external systems. DMS formats these, generating metadata if required, and transmits them using TCP/IP.

3.2.4 Functional Description

The major functions of the DMS are depicted in Figure 3-4. A description of these functions is presented below.

3.2.4.1 Ingest Data

The Ingest Data function provides the capabilities required to ingest and store data from systems external to IAS. The primary subfunctions include:

- Handling TCP/IP protocols
- Monitoring data receipt directories for the arrival of data from external systems
- Recognizing input data types and storing them accordingly
- Extracting files from the Level 0R Product and generating a record to maintain associations between them
- Updating the availability status of ingested data for Work Order processing
- Converting ephemeris files to internal format

3.2.4.2 Quality Check L0R Product

The Quality Check L0R Product function performs quality checks on the metadata, PCD, MSCD, and Calibration Parameter files bundled in the Level 0R Product received from the EDC DAAC. Corrections are applied to the PCD and MSCD.

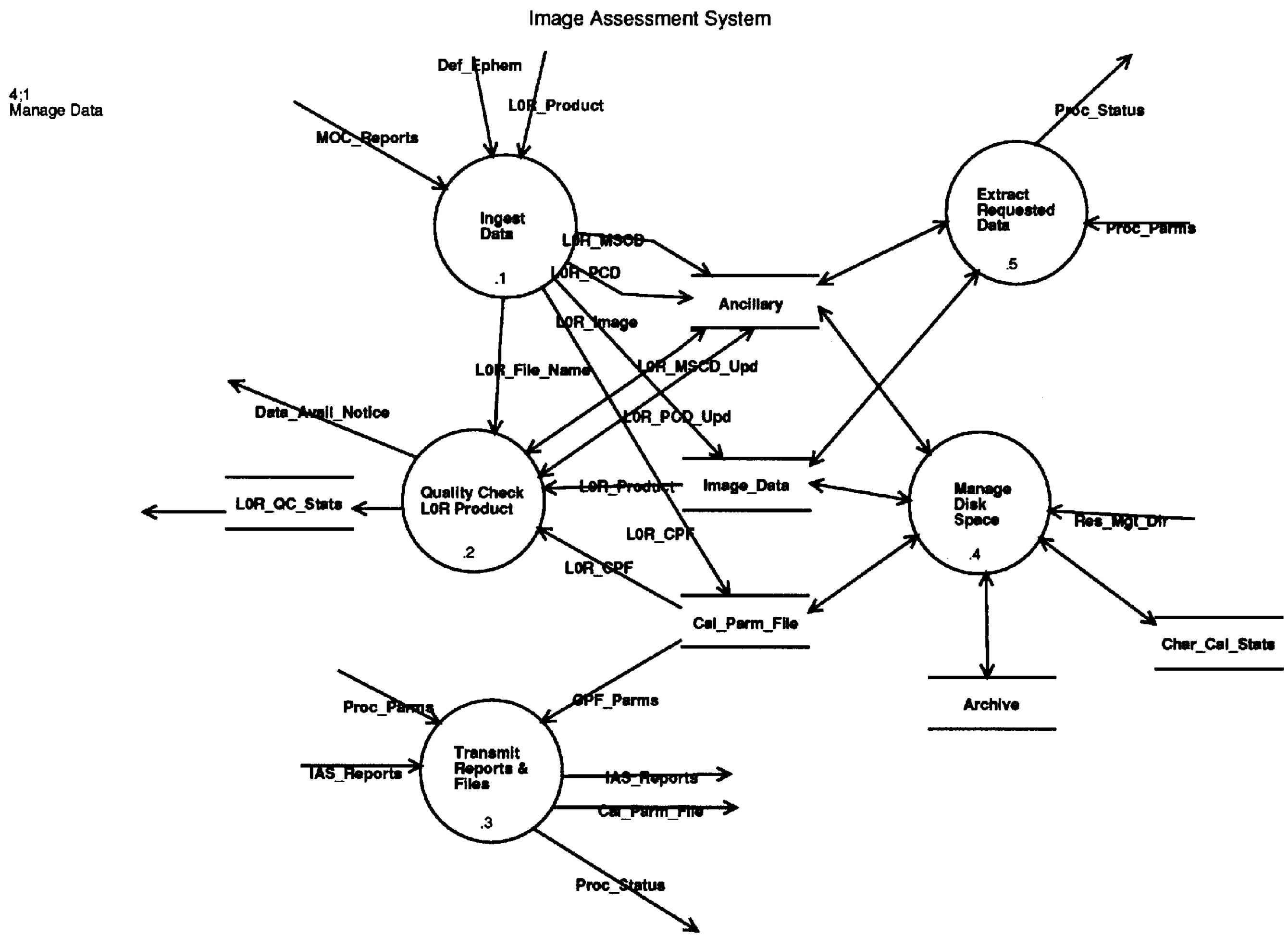


Figure 3-4. DMS Level 0 Data Flow Diagram

3.2.4.3 Extract Requested Data

The Extract Requested Data function extracts regions of the ingested L0R Product files for processing based on the scene corners or image window specified in the Work Order. The appropriate PCD data are always extracted from the PCD subinterval file. Additionally, the image data are extracted for any requests that do not fall on scene boundaries.

3.2.4.4 Transmit Reports and Files

The Transmit Reports and Files function provides the capability to assemble output products from IAS data stores, format them as required, and transmit them to external systems. The primary subfunctions include:

- Retrieving the data to be transmitted from IAS data stores
- Assembling the output product in the required format and generating and appending metadata, if any
- Handling TCP/IP communication protocols

3.2.4.5 Manage Disk Space

The Manage Disk Space function provides traditional file management services including establishing directories and allocating disk space for Work Order execution, and deleting associated files upon the completion of Work Order execution. This function also provides the capability to transfer data (and software) from on-line data stores to the archive and to restore data sets from the archive.

3.2.5 Data

This section describes the data flows and data stores appearing in Figure 3-4.

Ancillary (store) = All “ancillary” datasets needed for processing image data. Includes PCD + MSCD + Def_Ephem.

Archive (store) = Archive. Off- or near-line physical storage of Landsat data and software.

Cal_Parm_File (data flow) = Calibration Parameter File.

Char_Cal_Stats (store) = Characterization/Calibration Statistics. Statistics generated by characterization or calibration algorithm. Incorporates the results of the "Mask". Includes. DL_Stats + IN_Stats+ RN_Stats + AD_Sat_Stats + QA_Stats + SCS_Stats + CN_Stats + IC_Gain + IC_Offset + Scene_Bias. In IAS also includes L0R_QC_Stats .

CPF_Parms (data flow) = Calibration Parameter File Parameters. Refers to any field in a calibration parameter file.

Data_Avail_Notice (data flow) = Data Availability Notice. Notifies the recipient of the availability of data for processing..

IAS_Reports (data flow) = IAS Reports. Reports generated by IAS. Includes Assessment Reports, Anomaly Reports and Problem Reports.

Image_Data (store) = Image Data. Refers to image files input to IAS (L0R image data) or generated by IAS (L0Rc image data, L1R image data, and all varieties of L1G image data).

L0R_CPF (data flow) = Level 0R Calibration Parameter File. The version of the Calibration Parameter File bundled in the Level 0R Product..

L0R_File_Name (data flow) = L0R File Name. The file name assigned to a specific L0R scene..

L0R_Image (data flow) = L0R Image. The Level 0R Image files (1 per band) bundled in the Level 0R Product.

L0R_MSCD (data flow) = L0R Mirror Scan Correction Data. MSCD bundled in the Level 0R Product.

L0R_MSCD_Upd (data flow) = Updated L0R MSCD. L0R MSCD with various fields corrected.

L0R_PCD (data flow) = L0R Payload Correction Data . L0R PCD bundled in the Level 0R Product.

L0R_PCD_Upd (data flow) = Updated L0R PCD. L0R Payload Correction Data with various fields corrected and converted.

L0R_Product (data flow) = L0R Product. The product transmitted to IAS from the EDC DAAC containing L0r image and associated files. L0R_Image + L0R_CPF + L0R_MSCD + L0R_PCD.

L0R_QC_Stats (store) = L0R Quality Check Statistics. Statistics resulting from quality checking of the Level 0R Product files.

MOC_Reports (data flow) = Mission Operations Center Reports. Reports generated by the MOC that are of use to IAS. SC_Status_Report + Event_Schedule + TM_Trend_Report.

Proc_Parms (data flow) = Processing parameters. Parameters specified to control IAS application processing.

Proc_Status (data flow) = Processing Status. Processing execution status returned by an IAS application..

Res_Mgt_Dir (data flow) = Resources Management Directive. Operator directives for system resource allocations.

3.2.6 System/COTS Software

It is anticipated that the following system, COTS, and NDI software will be incorporated to provide some of the required system functionality:

- TCP/IP communication software
- ECS Ingest GUI to provide interface for exporting data to the ECS
- HDF toolkit for accessing fields in the MSCD and PCD and for formatting the Calibration Parameter File for export
- Oracle RDBMS for storing and retrieving characterization, assessment, and calibration results
- IRIX file management system for general file management services

3.2.7 Subsystem Hardware

The DMS executes in the IAS Operations System. No special purpose hardware is required.

3.3 Evaluation and Analysis (E&A) Subsystem

The E&A subsystem provides the tools required by an IAS Analyst to evaluate and analyze ETM+ instrument performance, perform anomaly investigations, and maintain the Calibration Parameter File. Included are capabilities for: viewing system inputs, processing reports, and results; data analysis; statistical analysis and trending; and report generation. Also included are capabilities for editing system inputs and intermediate results and for submitting processing requests in support of "what if" analyses.

3.3.1 Requirements Allocation

Table 3-5 provides the allocation of IAS system requirements to E&A. The requirements are not presented in numerical order; rather, related requirements are grouped together. The complete mapping of IAS system requirements to IAS subsystems is provided in Appendix A.

Table 3-5. E&A Subsystem Requirements Allocation

Number	Requirement Statement
3.2.2.4.16	The IAS shall provide a capability that allows an image analyst to monitor assessment processes and results.
3.2.2.6.13	The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.
3.2.2.4.17	The IAS shall have the capability to review output data, including but not limited to calibration reports and updates.
3.2.2.4.12	The IAS shall be able to evaluate the quality of Level 0R products. IAS shall: - provide the capability to visually check L0R Product imagery. - support validation of ACCA scores from the L0R Product metadata through visual inspection of the associated L0R image files
3.2.2.4.15	The IAS shall provide the capability to visually inspect image data.
3.2.2.6.10	The IAS shall have the capability to generate hardcopy outputs.
3.2.2.4.13	The IAS shall be capable of performing a trend analysis over any desired time interval for each selected evaluation activity.
3.2.4.14	The IAS capability shall be used in performing anomaly assessment, resolution, and reporting.
3.2.2.7.1	The IAS shall generate calibration, data quality assessment, and problem reports.
3.2.4.8	The IAS shall perform calibrations, assessments, and evaluations with frequencies (and reporting frequencies) specified in Tables 3.2.4-1 and 3.2.4-2. Reports shall include: - selected trend reports - quarterly calibration reports - quarterly assessment reports - monthly, quarterly, and annual evaluation reports
3.2.3.17	The IAS shall generate monthly reports that document the quality of 0R data and 0R products retrieved from the EDC DAAC.
3.2.3.18	The IAS shall provide regular calibration and performance updates to the EDC DAAC and other interfaces quarterly.
3.2.3.19	The IAS shall provide an annual Landsat 7 image quality report.
3.2.2.7.3	The IAS shall generate annual reports that document calibration coefficient and performance analysis trends.
3.2.2.7.4	The IAS shall generate reports of anomaly detection analyses as they are concluded.

3.3.2 Derived Requirements

Table 3-6 presents the derived requirements for the IAS Evaluation and Analysis Subsystem.

Table 3-6. E&A Derived Requirements

Number	Requirement Statement
E&A-1	E&A shall provide the following capabilities for displaying Work Order inputs, intermediate results, and outputs:
E&A-1.1	- Display of ASCII text reports from the Run Log
E&A-1.2	- Formatted display of binary non-image system inputs and intermediate datasets

E&A-1.3	- Color display of Level 0R and intermediate image datasets
E&A-1.4	- Scrolling over entire image
E&A-1.5	- Contrast stretch capability for individual line (detector), band or all bands displayed. Single band and line displays will be displayed with an accompanying (LUT). Multi-band displays will be displayed in user-selectable color planes.
E&A-1.6	- Windowing for multiple bands or multiple scenes
E&A-1.7	- Color display of up to three overlaid bands of image data at resolution from sub-scene full resolution to HDF sub-sampled resolution with capability of zooming between resolution levels
E&A-1.8	- Image mosaicing capability
E&A-1.9	- Display of line/pixel coordinates and pixel values at designated cursor location
E&A-1.10	- Formatted dump of image datasets
E&A-1.11	- Hardcopy print of image datasets
E&A-2	E&A shall provide the following data analysis capabilities:
E&A-2.1	- Pixel arithmetic functions for multiple band combinations
E&A-2.2	- Histogram analysis
E&A-2.3	- FFT analysis
E&A-2.4	- Statistical analysis package
E&A-2.5	- Trending of selected parameters, including regressions/curve fitting with measures of quality of fit
E&A-2.6	- Canned trending scripts for standard trending plots
E&A-2.7	- 1D, 2D, and 3D plotting capability, including scatter plots, line plots, image displays, contour, wireframe and shaded-surface displays
E&A-2.8	- Screen display of all plots/reports
E&A-2.9	- Control Point correlation capability
E&A-3	E&A shall provide the capability to edit system input files, including image, PCD, MSCD, and Calibration Parameter files in support of 'what if" analyses. E&A shall provide editable forms and perform sanity checks of modified parameters before accepting them.
E&A-4	E&A shall provide a user interface to custom IAS applications for radiometric and geometric assessment and evaluation. The Analyst and Operator interfaces shall have the same look and feel.
E&A-5	E&A shall provide the capability to generate reports summarizing ETM+ instrument and IAS system performance.
E&A-6	E&A shall provide the capability to insert plots and other statistical measures output by E&A data analysis applications into an analyst-generated report.

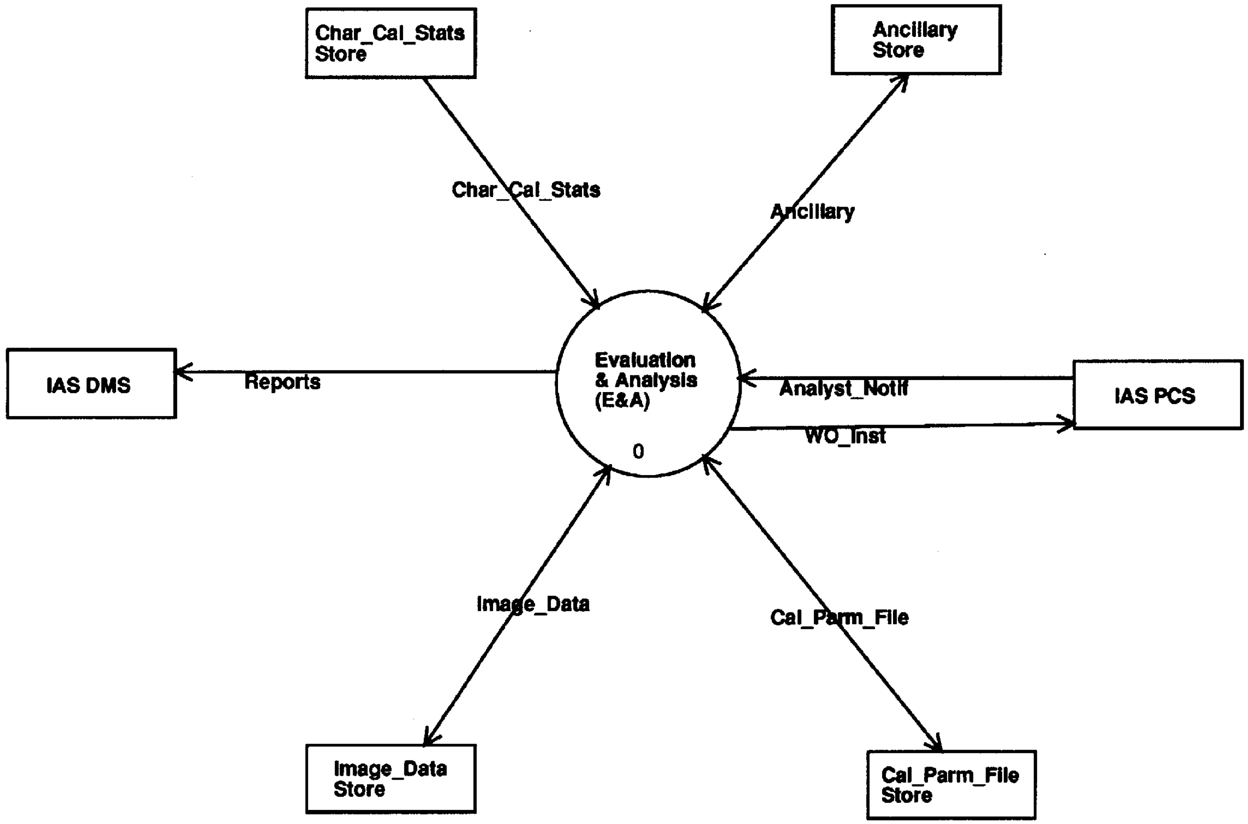


Figure 3-5. E&A Subsystem Context Diagram

3.3.3 Interfaces

The E&A context diagram, Figure 3-5, shows E&A interfaces to the other IAS subsystems. E&A functions are invoked by the IAS Analyst.

The E&A subsystem interfaces to the Radiometry and Geometry Processing Subsystems indirectly through the algorithms' input and output datasets. Algorithm inputs, including Level 0R image data, IC data, PCD, MSCD, GCP libraries, etc. are retrieved by E&A from designated run directories for viewing. The Analyst may use E&A capabilities to edit these inputs and rerun the processing using the Work Order

mechanism. Algorithm execution results, including characterization and calibration summary reports and statistics for trending, are input to E&A. Other statistics are input to E&A via the trending database. All intermediate files generated by these algorithms including 0Rc, 1R, and 1G image files as well as GCP residual files, precision solution files, etc. are retrieved by E&A from designated run directories for viewing.

E&A provides the User Interface for invoking certain stand-alone applications within the Radiometry and Geometry Processing subsystems, and for initiating Work Orders.

Reports are generated on a monthly and quarterly basis for distribution to the MMO and other external interfaces. Distribution services are provided by the Data Management System (DMS).

3.3.4 Functional Description

Figure 3-6 contains the E&A's level 0 data flow diagram. The diagram shows the E&A's primary functions. Those functions are described in the subsections below.

3.3.4.1 Display IAS Data

The Display IAS Data function provides the IAS Analyst with a variety of tools for displaying the inputs to and the results of Level 1, Calibration, and Assessment/Characterization processing. Included are capabilities for ASCII text file display, formatted binary file display, and graphical image display. Image displays will be on user-selectable map-projection coordinate systems. Geographic boundaries may be displayed.

3.3.4.2 Edit IAS Data

The Edit IAS Data function allows the IAS Analyst to modify any file input to a Work Order for the purpose of performing "what if" analyses. Files that may be edited include image files, PCD, MSCD, Calibration Parameter File, GCP residuals, and any other Work Order input files.

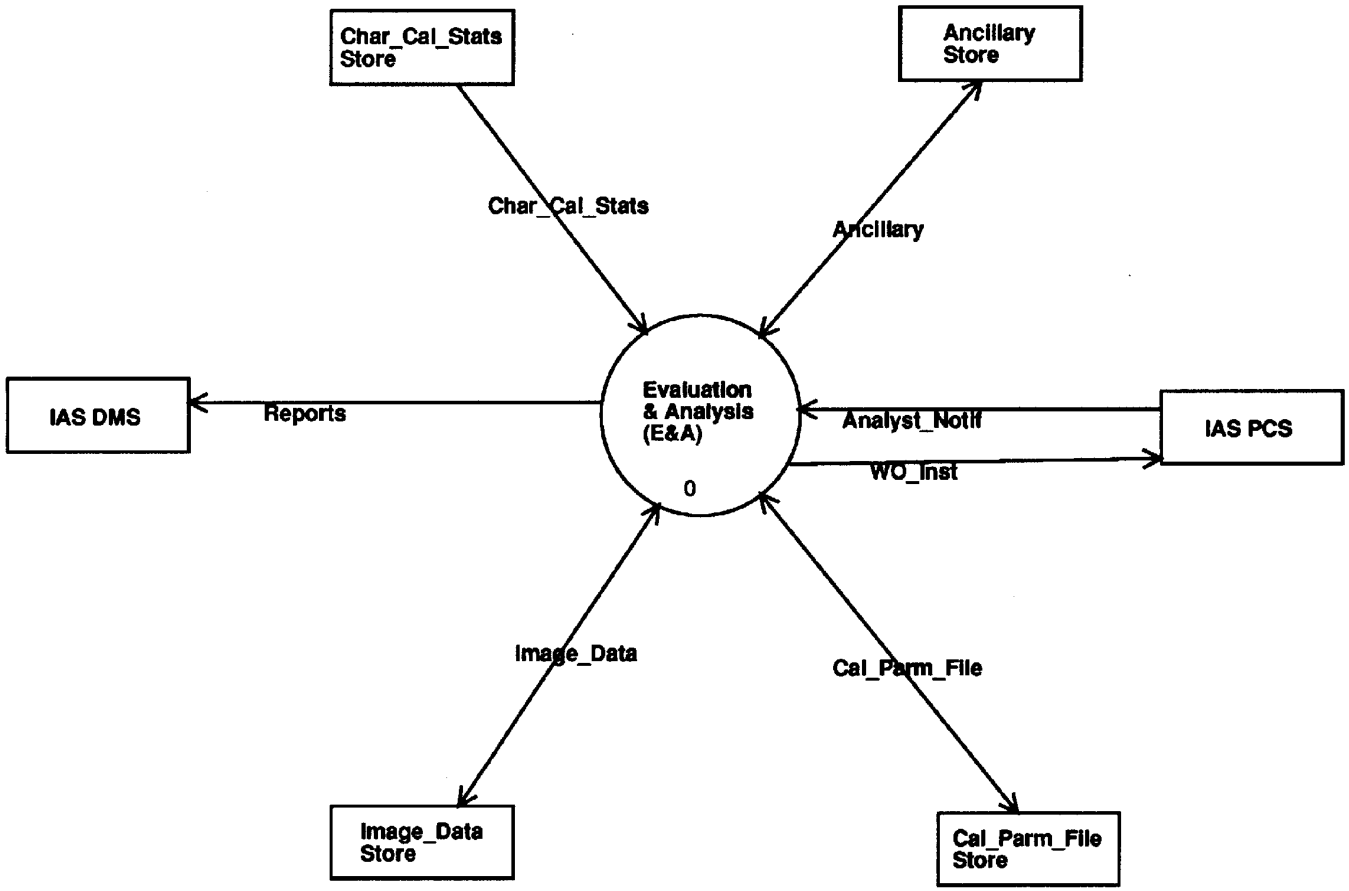


Figure 3-6. E&A Subsystem Level 0 DFD

An editor function will be provided to prevent the user/analyst from making obvious mistakes. Where applicable, edited data fields will be checked to make sure they do not contain incorrect data (out of bounds, text entry in numeric field, etc.).

3.3.4.3 Analyze IAS Data

The Analyze IAS Data function provides statistical analysis, trending, and image manipulation capabilities. These functions are used to conduct a more analytical evaluation of processing inputs and outputs, to summarize large volumes of data, and to support the analyst in visualizing trends and problems.

3.3.4.4 Generate Reports

The Generate Reports function is used to generate monthly, quarterly, and annual formatted reports summarizing ETM+ instrument and IAS system performance for output to the MMO and other external recipients. The function provides for formatted text entry as well as the ability to incorporate graphics generated by data analysis packages.

3.3.4.5 Submit Jobs

The Submit Jobs function is used by the IAS Analyst to execute stand-alone Radiometry or Geometry Processing Subsystem applications or to submit Work Orders for execution.

3.3.4.6 Provide Analyst Interface

TBS

3.3.5 Data

This section describes the data flows and data stores appearing in Figure 3-6.

Analysis_Res (data flow) = Analysis Results. Results generated by an analysis application..

Analyst_Notif (data flow) = Analyst Notification. Automated notification of the IAS Analyst that processing results are available for review.

Ancillary (store) = All “ancillary” datasets needed for processing image data. Includes PCD + MSCD + Def_Ephem.

Cal_Parm_File (data flow) = Calibration Parameter File.

Char_Cal_Stats (store) = Characterization/Calibration Statistics. Statistics generated by characterization or calibration algorithm. Incorporates the results of the "Mask". Includes. DL_Stats + IN_Stats+ RN_Stats + AD_Sat_Stats + QA_Stats + SCS_Stats + CN_Stats + IC_Gain + IC_Offset + Scene_Bias. In IAS also includes L0R_QC_Stats .

Image_Data (store) = Image Data. Refers to image files input to IAS (L0R image data) or generated by IAS (L0Rc image data, L1R image data, and all varieties of L1G image data).

L0R_QC_Stats (store) = L0R Quality Check Statistics. Statistics resulting from quality checking of the Level 0R Product files.

Op_Inst (data flow) = Operator Instructions.

Proc_Parms (data flow) = Processing parameters. Parameters specified to control IAS application processing.

Reports (data flow) = Reports. Reports sent from IAS to external entities.

WO_Inst (data flow) = Work Order Instructions. Instructions issued by an IAS Operator or Analyst specifying Work Order parameters or control directives.

3.3.6 System/COTS Software

The E&A software comprises mostly COTS applications code. The vast majority of the required functionality for data display, editing, and analysis will be provided by the Interactive Data Language (IDL) and the Environment for Visualizing Imagery (ENVI). The report generation capabilities will be provided through Oracle, FrameMaker, and the IDL text editor. The job submission capabilities will be provided, in part, through IDL.

3.3.7 Subsystem Hardware

The E&A subsystem executes on SGI O2 workstations. There will be 2 such workstations, one for each of the IAS Analysts. The Indigos will be attached to the LAN from which they can access the RAID disks containing the outputs of the Radiometry and Geometry Processing Subsystems. The E&A “generic” image processing and analysis applications will be executed on the Indigos. Custom standalone radiometry and geometry evaluation and analysis applications will be executed remotely on the “operations machine” via the E&A interface. Requests for Level 1 processing will be initiated remotely over the LAN using the PCS Work Order mechanism.

3.4 Radiometric Processing Subsystem (RPS)

The Radiometric Processing Subsystem (RPS) performs radiometric calibration and level 1R processing. The purpose of radiometric calibration is to determine the calibration in-flight of each detector, that is, the conversion from digital number to absolute radiance. The primary purpose of the level 1R processing is to convert the brightness of the image pixels to absolute radiance, and is done prior to level 1 geometric processing. This process uses various ground and in-flight determined calibrations. Another function of level 1R processing is to characterize the quality and various features of the data.

3.4.1 Requirements Allocation

Table 3-7 provides the allocation of IAS system requirements to the Radiometric Processing Subsystem. The requirements are not presented in numerical order; rather, related requirements are grouped together. The complete mapping of IAS system requirements to IAS subsystems is provided in Appendix A.

Table 3-7. Radiometric Processing Subsystem Requirements Allocation

Reqt Number	Requirement Statement
3.2.2.6.13	The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.
3.2.2.7.1	The IAS shall generate calibration, data quality assessment, and problem reports.
3.2.4.8	The IAS shall perform calibrations, assessments, and evaluations with frequencies specified in Tables 3.2.4-1 and 3.2.4-2.
3.2.2.4.12	The IAS shall be able to evaluate the quality of Level 0R products. Quality checks will include but not be limited to those listed in Table 3.2.2.4-1.
3.2.2.7.5	The IAS shall generate processing summaries after each IAS activity.
3.2.4.8s	The IAS shall evaluate Level 0R data and products.
3.2.4.8g	The IAS shall perform radiometric accuracy assessments.
3.2.2.1.1	The IAS shall be able to use data from the internal calibrator in the calibration of the radiometric response of each ETM+ detector.
3.2.2.1.2	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the partial-aperture solar calibrator (PASC).
3.2.2.1.3	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the full-aperture solar calibrator (FASC).
3.2.2.1.4	The IAS shall be able to calibrate the radiometric response of each ETM+ detector given Level 0R data of a ground calibration site and corresponding at-aperture spectral radiance values.
3.2.2.1.5	The IAS shall be able to calibrate the radiometric response of each ETM+ detector using Level 0R data from preship and prelaunch calibration sources and auxiliary calibration source data.

3.2.2.1.6	The IAS shall have the capability of assessing the short-term and long-term stability of the onboard calibration sources, which include the FASC, the PASC, and the internal calibrators.
3.2.2.1.7	The IAS shall be able to integrate the results of the various calibration processes into an optimal estimate of radiometric calibration of each detector (except band 6) and provide new calibration parameters.
3.2.2.1.8	The IAS shall be capable of generating radiometric calibration updates for the calibration parameter file.
3.2.2.1.9	The IAS shall be able to transfer the calibration of each detector to the internal calibrator.
3.2.2.3.2	The IAS shall be capable of processing ETM+ Level 0R products to produce radiometrically corrected Level 1R image data.
3.2.2.3.15	The IAS shall be capable of processing to Level 1R and 1G both ascending and descending pass ETM+ Level 0R data.
3.2.2.3.7	The IAS shall be capable of incorporating IAS-generated calibration coefficient updates to generate Level 1 data.
3.2.2.3.13	The IAS shall be capable of compensating for inoperable and saturated detectors during Level 1R and 1G processing.
3.2.2.3.14	The IAS shall be capable of compensating for the image artifacts of striping, banding, coherent noise, memory effect, and scan correlated shift in Level 1R and 1G processing.
3.2.2.4.1	The IAS shall evaluate the on-orbit operability of ETM+ detectors.
3.2.2.4.2	The IAS shall be able to evaluate the absolute radiometric accuracy of ETM+ Level 0R, 1R, and 1G data.
3.2.2.4.3	The IAS shall be able to assess the identified ETM+ radiometric image artifacts of striping; banding; random, correlated, and coherent noise; memory effect; and scan-correlated shift.
3.2.2.4.4	The IAS shall be able to evaluate the MTF of each ETM+ detector.
3.2.2.4.5	The IAS shall be able to evaluate the signal-to-noise ratio (SNR) of each ETM+ detector, using prelaunch and on-orbit image data.
3.2.2.4.6	The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector with respect to dynamic range.
3.2.2.4.7	The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector, excluding band 6, with respect to linearity (TBD).
3.2.2.4.12f	The IAS shall validate dropped line locations in the L0R Product Mirror Scan Correction Data.
3.2.2.4.12m	The IAS shall validate calibration outliers in the L0R Product Calibration Pulse/Shutter data.
3.2.2.4.12n	The IAS shall validate shutter means in the L0R Product Calibration Pulse/Shutter data.
3.2.2.4.12o	The IAS shall validate shutter standard deviations in the L0R Product Calibration Pulse/Shutter data.
3.2.2.4.12p	The IAS shall validate shutter outliers in the L0R Product Calibration Pulse/Shutter data.
3.2.3.1	The IAS shall be capable of calibrating the radiometric response (absolute spectral radiance) of each operable ETM+ detector to an accuracy of 5 percent, 1 sigma, providing all inputs are within specification.
3.2.3.2	The IAS shall be capable of calibrating the relative radiometric response such that the

	ratio of ETM+ equivalent at-aperture radiances between any combination of two spectral bands, excluding band 6, shall vary less than 2 percent, 1 sigma, over a 7-day p
3.2.3.3	The IAS shall contribute no greater than 0.7 percent uncertainty to absolute radiometric accuracy during the generation of Level 1R and 1G data.
3.2.4.8d	The IAS shall perform radiometric calibrations.
3.2.4.8f	The IAS shall perform detector operability assessments.
3.2.4.8h	The IAS shall perform streaking and banding assessments.
3.2.4.8i	The IAS shall perform correlated and coherent noise assessments.
3.2.4.8j	The IAS shall perform MTF assessments.
3.2.4.8k	The IAS shall perform SNR assessments.
3.2.4.8p	The IAS shall perform Image artifact assessments.
3.2.4.8t	The IAS shall evaluate Level 1R data quality.

3.4.2 Derived Requirements

The derived requirements for the Radiometric Processing Subsystem are documented in the radiometric algorithm descriptions and the Radiometry Algorithm Theoretical Basis Document (ATBD). These documents can be located on the World Wide Web at URL http://ltpwww.gsfc.nasa.gov/LANDSAT.

3.4.3 Interfaces

The Radiometric Processing Subsystem context diagram, Figure 3-7, shows RPS interfaces to the other IAS subsystems. The RPS has a direct interface with the Process Control Subsystem and indirect interfaces through input and output files with the rest of the IAS subsystems.

PCS activates RPS, sending user-specified processing parameters to control the specific algorithms invoked during processing. RPS reports processing status back to PCS upon completion of processing.

Context-Diagram;3
Landsat 7 IAS Radiometry Processing Subsystem

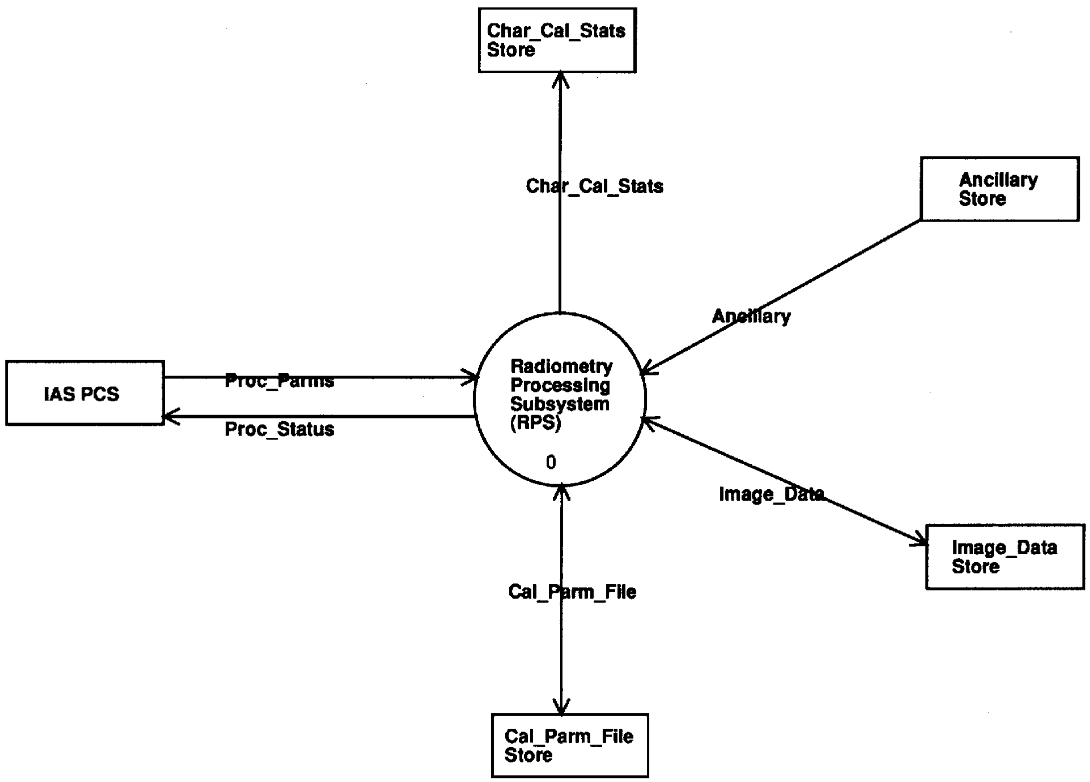


Figure 3-7. RPS Context Diagram

RPS interfaces indirectly to the Geometric Processing Subsystem through the Image data store. Level 1R images generated by RPS are input to the 1G processing.

RPS interfaces indirectly to the Data Management Subsystem through the Calibration Parameter File (CPF) database. The HDF-formatted CPF is generated from these data elements by DMS for transmission to external systems.

The RPS interface to the Evaluation and Analysis subsystem is also indirect. RPS generates characterization and calibration results and statistics for trending analysis, intermediate image products, and run reports. These data are stored in various data stores and are retrieved by the IAS Analyst using E&A tools for viewing and analysis.

3.4.4 Functional Description

Figure 3-8 presents the RPS Level 0 data flow diagram depicting the subsystem's primary functions. Those functions are described in the following sections.

3.4.4.1 Radiometric Calibration

The dataflow for this function is shown in Figure 3-9. In addition to the three functions shown, processing of the IC data (emissive and reflective) is part of calibration in the algorithm descriptions, but is performed as part of 1R processing, and so is discussed there

Process PASC (Algorithm 3.1) This function processes Partial Aperture Solar Calibrator (PASC) data and calculates gains and biases for each detector based on that detector’s response to the Sun image.

Process FASC (Algorithm 3.2) This function processes Full Aperture Solar Calibrator (FASC) data and calculates gains and biases for each detector based on that detector’s response to the Sun image.

Combined Radiometric Model (Algorithm 3.6) The CRaM optimally combines inputs from all ETM+ radiometric calibrations sources into a net calibration for each detector.

3.4.4.2 Level 1R Processing Subsystem

The Level 1R processing flow for day scenes is depicted in Figure 3-10. This flow is a superset of the Level 1R processing to be performed on other types of scenes (e.g., night scenes, MTF scenes, etc.). Level 1 processing flows for all scene types are depicted in section 5.

Level 1R processing is broken into the 5 major processing steps described below.

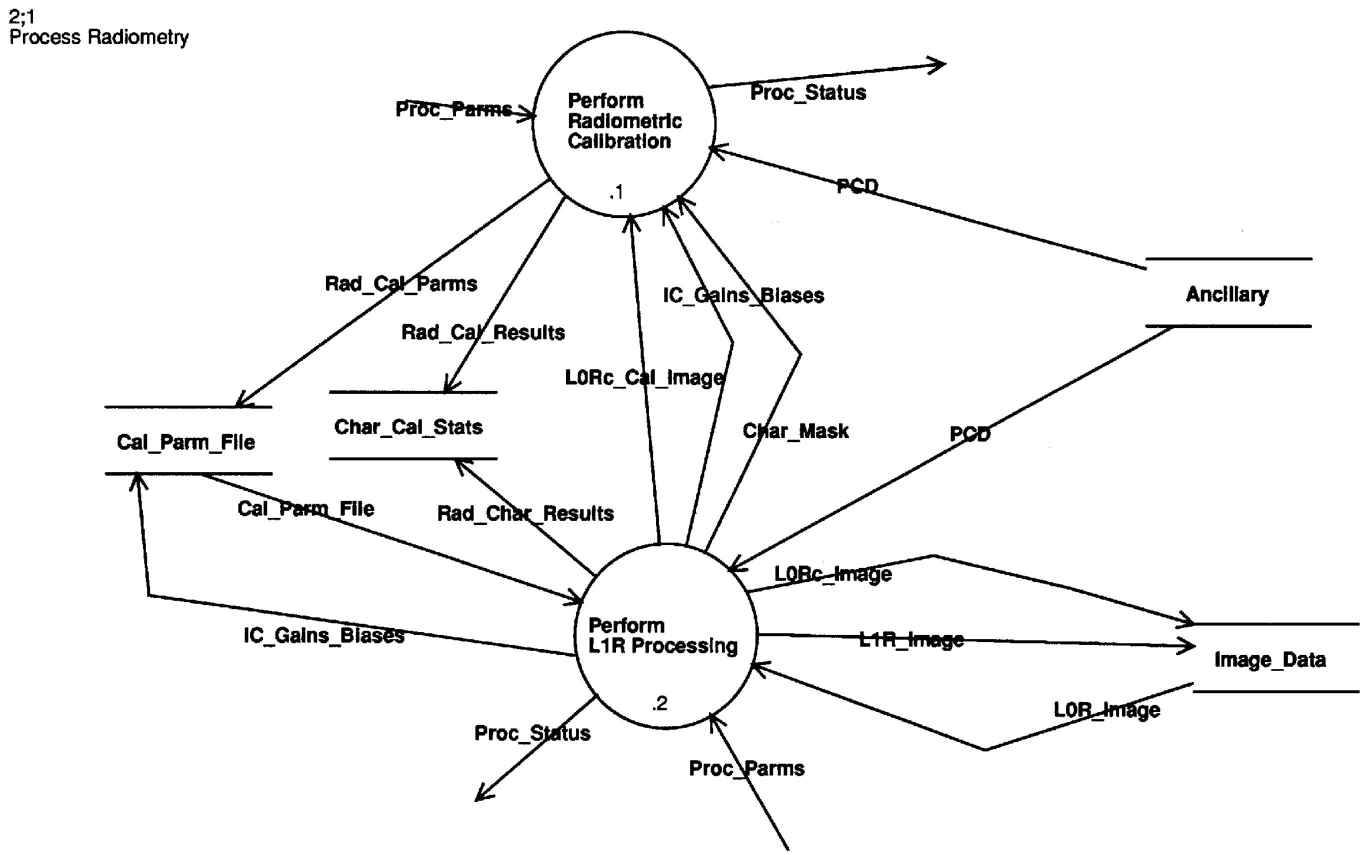


Figure 3-8. RPS Level 0 DFD

2.1;1
Radiometric Calibration

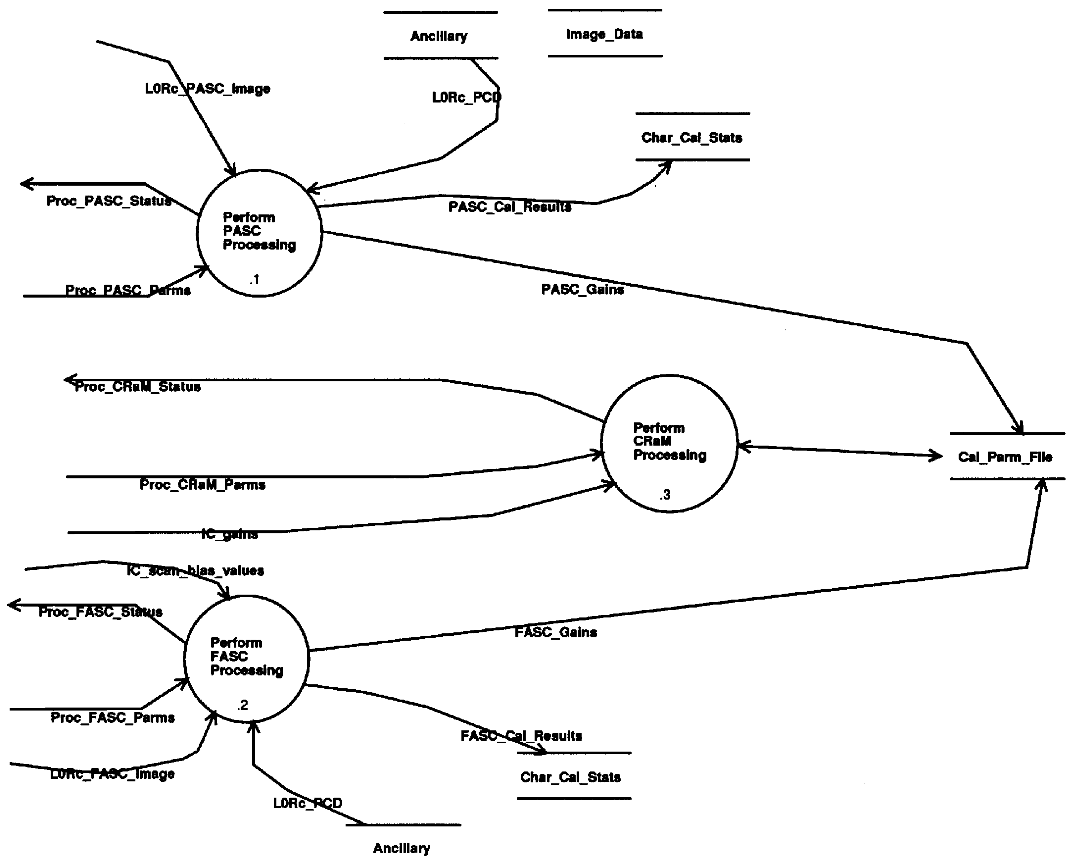


Figure 3-9. Radiometric Calibration DFD

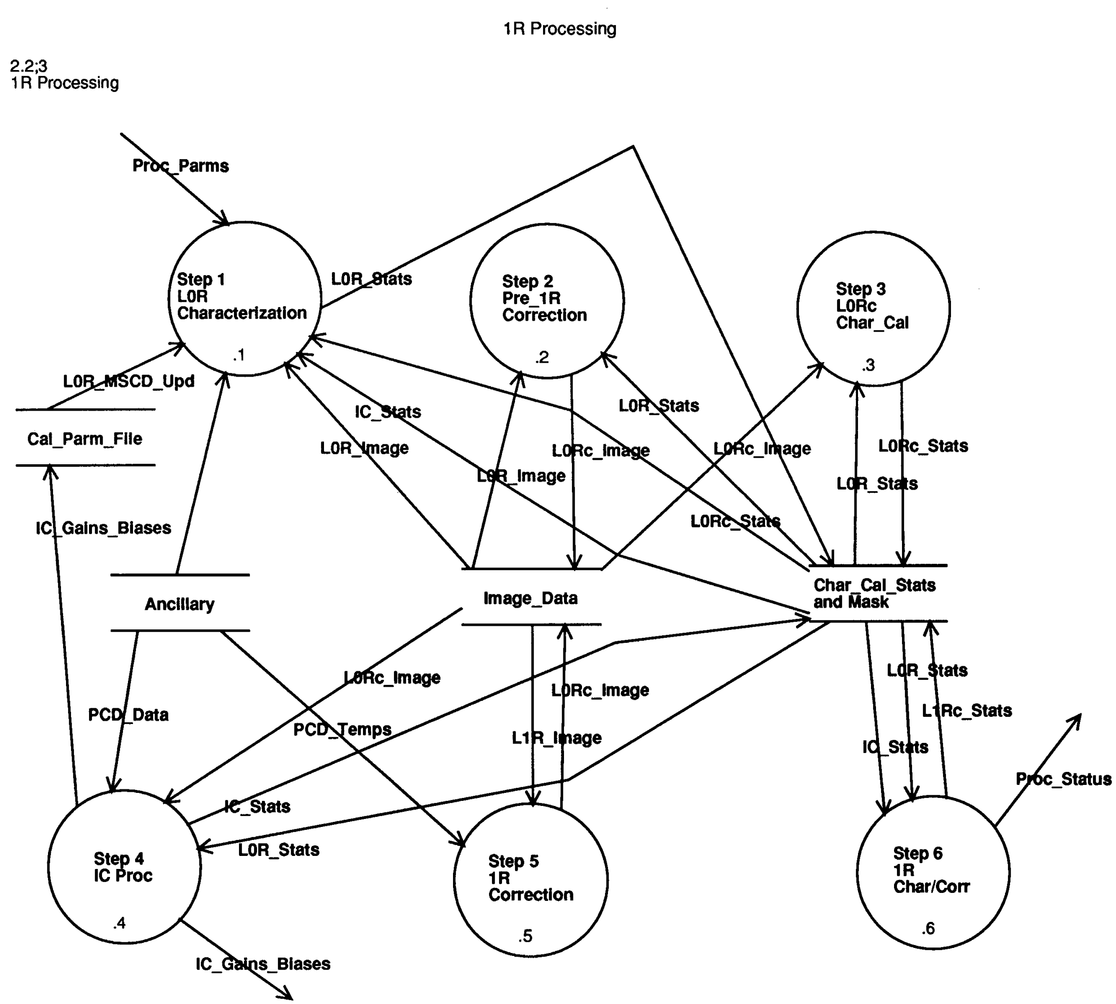


Figure 3-10. Level 1R Processing Subsystem Flow

3.4.4.2.1 0R Radiometric Characterization (Step 1)

In the 0R Radiometric Characterization step, several radiometric artifacts are located in the image and internal calibrator (IC) data so these regions can be skipped during radiometric characterization. The following algorithms are executed in this step:

Locate Dropped Lines (Algorithm 2.5) This algorithm searches for a dropped line fill pattern (applied in Level 0 processing) and marks those locations.

Characterize Impulse Noise (Algorithm 2.1). This algorithm searches for pixels with a much different brightness than nearby ones.

Locate Saturated Pixels (Algorithm 2.6). This function searches for pixels having pre-determined values near 0 or 255 which represent saturated detectors or A/D converters.

Characterize Scan Correlated Shift (Algorithm 2.3). The detectors used in the ETM+ periodically change their gain between two states (this is not the same as the command gain change that affects all the detectors). This function locates these shift points and marks them.

Characterize Coherent Noise (Algorithm 2.4). This function locates small periodic shifts in pixel brightness.

Histogram Analysis (Algorithm 2.10). This function performs a histogram analysis to identify detector saturation levels and to provide characterization of the 0R image.

3.4.4.2.2 Pre-1R Correction (Step 2)

The Pre-1R Correction step corrects for certain image artifacts prior to the conversion from digital numbers to absolute radiance. These corrections require the image and IC data to be logically combined, and so the first and last algorithms do the combining and then the separating. The following algorithms are executed during this step:

Correct SCS (Algorithm 4.1.3). This algorithm corrects the SCS identified in the previous step, using SCS levels from the database.

Correct Coherent Noise (Algorithm 4.1.4). This algorithm corrects the coherent noise located in the previous step.

Correct Memory Effect (Algorithm 4.1.2). This function corrects for memory effect, which is a shift in the brightness of the pixels which persists for a period of time after a bright exposure.

3.4.4.2.3 0Rc Radiometric Characterization/Calibration (Step 3)

The 0Rc Radiometric Characterization/Calibration step repeats some of the 0R characterizations on the 0R corrected image to determine the effect of the pre-1R corrections. The following algorithms are executed during this step:

Characterize Detector Saturation (Algorithm 2.6). This function searches for pixels having pre-determined values near 0 or 255 which represent saturated detectors, A/D converters or telemetry.

Characterize Random Noise (Algorithm 2.9). This algorithm attempts to measure random noise by calculating means and standard deviations on IC data, where the radiances are expected to be constant.

Histogram Analysis (Algorithm 2.10). This function performs a histogram analysis to identify detector saturation levels and to provide characterization of the 0Rc image.

Characterize Detector Operability (Algorithm 2.7). The purpose of this function is to develop a measure of how well each detector is working. Criteria include a detector's noise level, whether it responds to calibration lamp pulses, and saturation levels.

3.4.4.2.4 Process IC Data (Step 4 A)

At the end of each scan, the instrument collects IC data as an aid to converting the measurements to absolute radiance. The calibrator consists of two parts -- a shutter to provide a known near zero radiance and a set of lamps to provide a known high radiance. The following algorithms are executed during this step:

Process IC Emissive Band Data (Algorithm 3.4.1). This function processes the IC data for the emissive (thermal) band and calculates gains and biases for each detector based on that detector's response to the shutter and the calibration lamps.

Process IC Reflective Band Data (Algorithm 3.4.2). This function processes the IC data for the reflective bands and calculates gains and biases for each detector based on that detector's response to the shutter and the calibration lamps.

3.4.4.2.5 1R Radiometric Correction (Step 4B)

In this step the previously calculated gains and biases are applied to the scene data to convert to digital numbers to absolute radiance. Gains can come either from the Process IC functions applied to the current scene, or from several other sources. The following algorithms are executed during this step:

Gain Switch (Algorithm 6.5). The operator uses the gain switch to select between three sources: The IC gains computed in the process IC function, prelaunch gains, or gains from the combined radiometric model.

Apply Radiometric Correction (Algorithm 4.2). The selected calibrations are actually applied here.

3.4.4.2.6 1R Radiometric Characterization/Correction (Step 5)

In this step, a final histogram analysis is performed to assess the quality of the corrections. Also, a number of artifacts are optionally corrected in order to produce a “cosmetically correct” image. The following algorithms are executed during this step:

Histogram Analysis (Algorithm 2.10)

Correct for Dropped Lines and Inoperable Detectors (Algorithms 4.3.1 and 4.3.2). Artifacts which were flagged in Step 1 are corrected here by interpolating from unflagged adjacent parts of the image or substituting fill values.

Characterize Banding (Algorithm 4.3.6). Banding should have been removed by correction process in earlier steps of the level 1 process, and this algorithm provides a final characterization.

Correct Striping and Banding (Algorithms 4.3.4 and 4.3.5). As mentioned above, these effects should have been removed by the previous corrections. In the event they were not, and a clean picture is needed, these corrections can be applied at this point.

3.4.5 Data

This section defines the data flows and data stores appearing in Figure 3-8.

Ancillary (store) = All “ancillary” datasets needed for processing image data. Includes PCD + MSCD + Def_Ephem.

Cal_Parm_File (data flow) = Calibration Parameter File.

Char_Cal_Stats (store) = Characterization/Calibration Statistics. Statistics generated by characterization or calibration algorithm. Incorporates the results of the "Mask". Includes. DL_Stats + IN_Stats+ RN_Stats + AD_Sat_Stats + QA_Stats + SCS_Stats + CN_Stats + IC_Gain + IC_Offset + Scene_Bias. In IAS also includes L0R_QC_Stats .

Char_Cal_Stats and Mask (store) = Store incorporating both Char_Cal_Stats and Mask.

Char_Mask (data flow) = Characterization Mask. The data structure generated during radiometric characterization to record the locations of and extent of radiometric artifacts.

IC_Stats (data flow) = Shutter_Pulse_Values + IC_Gains_Biases + Dead_Det _ Lamp_Stats

IC_Gains_Biases (data flow) = IC Gains and Biases. Gains and biases generated as a result of IC processing.

Image_Data (store) = Image Data. Refers to image files input to IAS (L0R image data) or generated by IAS (L0Rc image data, L1R image data, and all varieties of L1G image data).

L0R_Image (data flow) = L0R Image. The Level 0R Image files (1 per band) bundled in the Level 0R Product. Plus IC.

L0R_Stats (data flow) = Level 0R Image Statistics. Includes DL_Stats + IN_Stats + DS_Stats + SCS_Stats + AD_Sat_Level + Rel_Gains_Biases.

L0Rc_Cal_Image (data flow) = Corrected L0R Calibration Image = L0Rc_PASC_Image +L0Rc_FASC_Image + L0Rc_IC_Data.

L0Rc_Image (data flow) = L0Rc Image. Level 0R image with corrections applied for certain radiometric artifacts (scan-correlated shift, coherent noise, and memory effect). Plus IC.

L0Rc_Stats (data flow) = Level 0Rc Image Statistics. Includes Sat_loc + RN_Stats + Det_SNR + Det_Stats + Sat_Levels + Rel_Gains_Biases _ Analog_Sat_Levels

L1R_Image (data flow) = Level 1R Image. Landsat image data with radiometric corrections applied. Plus IC.

L1R_Stats (data flow) = Level 1R Image Statistics. Banding_Stats + Det_Ops_Stats

PCD_Data (data flow) = Payload Correction Data. Includes PCD_Lamp_States + PCD_Temps + ETM_Ontime.

Proc_Parms (data flow) = Processing parameters. Parameters specified to control IAS application processing.

Proc_Status (data flow) = Processing Status. Processing execution status returned by an IAS application..

Rad_Cal_Parms (data flow) = Radiometric Calibration Parameters. Parameters used to control radiometric calibration processing.

Rad_Cal_Results (data flow) = Radiometric Calibration Results. Results of performing radiometric calibration processing.

Rad_Char_Results (data flow) = Radiometric Characterization Results. Results of performing radiometric characterization processing.

3.4.6 System/COTS Software

NCSA HDF tools will be used for retrieving Level 0R image, MSCD, and PCD data and for writing out Level 0Rc and Level 1R image files.

Oracle APIs will be used for storing and associating radiometric characterization and calibration results with the processed scene or with specific detectors.

3.4.7 Subsystem Hardware

The RPS executes in the IAS Operations System. No special purpose hardware is required.

Section 4. System Support Software

This section specifies the system support software included in the IAS system design. Section 4.1, "IAS System Software," describes the operating system and device interface software specified for the IAS system design. Section 4.2, "IAS COTS Software," specifies COTS application software specified for the IAS system design. Section 4.3, “IAS NDI Software” specifies the NDI application software specified for the IAS system design

4.1 IAS System Software

IAS system software includes the IRIX operating system, device drivers, and communications software.

4.1.1 IRIX Operating System

The software architecture includes a version of the UNIX operating system both because UNIX provides an open system which enhances application portability and because a wide selection of UNIX-based commercial applications are available.

SGI’s IRIX operating system is the UNIX variant that is bundled with the SGI Challenge XL computers that comprise the Operational System HWCI. IRIX Version 6.4, which incorporates a 64-bit architecture, shall be used as the IAS operating system for the SGI Origin 2000. IRIX Version 6.2 shall be used for the Challenge XL and Challenge L.. The use of 64-bit technology has allowed SGI to overcome previous UNIX file size limitations of 2GB.

4.1.2 Device Driver Software

Devices to be added to any of the platforms in the network require the use of device driver software. For standard devices manufactured by the platform manufacturer, these drivers are generally bundled in the operating system. For third-party devices, the drivers are generally included with the device.

Specific device drivers are TBD at this time. Drivers will be required for:

- RAID devices
- DLT drives

- 8 mm tape drives

4.1.3 Communications Software

A commercial TCP/IP package will be used for communication with external systems and for controlling internal Ethernet and FDDI network communications.

4.2 IAS COTS Application Software

IAS COTS software includes the Oracle DBMS, the NCSA HDF software package, and the IDL and ENVI image display and analysis software.

4.2.1 Oracle DBMS

Oracle is a relational database management system (RDBMS). An IAS design constraint is to use Oracle should there be a need for an RDBMS.

Oracle provides standard management services for information stored as a set of relations (tables). It also manages the storage of views, rules, triggers, constraints, and procedures within a database. Standard database management features include transaction based commit and rollback, two-phase commit for distributed databases, journaling and checkpointing, and database consistency point recovery after catastrophic system failures. It includes [optional] modules for forms-based user interface, report generation, stored procedure definition, and C language Applications Programming Interface (API).

These Oracle capabilities will be used for Work Order data entry, storage and manipulation, for managing characterization and calibration statistics and related data, and for report generation

Oracle uses a SQL based data definition and manipulation language. This capability shall be available to IAS users for direct querying of the database.

Oracle includes both line-oriented and forms-based SQL user interfaces for data definition, data manipulation, and database administration. Database access is controllable by passwords and access permissions. PL/SQL is Oracle's procedural language with embedded SQL; it can be used to define stored procedures. Oracle includes a C pre-compiler and run-time libraries that provide an embedded SQL API.

Oracle includes standard database administration utilities including save/restore, data import/export, system configuration, and access permission and system privilege control. Access permission and privilege granularity is at the table and operation level. Oracle allows the definition of roles, a set of system privileges and data access privileges on database objects that may be granted/revoked to a user as a unit. Oracle's auditing capabilities allow the generation of access histories for system tuning.

4.2.2 NCSA HDF

NCSA HDF is a collection of run-time libraries and utilities that support creation and manipulation of files in the HDF standard. The file format standard, run-time libraries, and utilities were developed by NCSA with the goal of allowing data sharing via files in a standard, flexible, and machine-independent format.

HDF has been adopted as a standard for Earth sciences files stored in the Earth Observing System Data and Information System (EOSDIS). Level 0R Product files transmitted to IAS from the EDC DAAC will be in HDF format. For commonality with LPGS, IAS internal image files (0Rc, 1R, and 1G) will be stored in HDF.

IAS applications software will be linked with HDF run-time libraries to manipulate Level 0R Product files and to store internally-generated image files in HDF format. IAS operators may use HDF utilities to view and edit HDF files directly.

4.2.3 Interactive Data Language (IDL)

The Interactive Data Language (IDL) from Research Systems, Inc. (RSI) is a COTS packages for data analysis, visualization, and application development. IDL has been selected to provide some of the functionality required for the Evaluation and Analysis subsystem, and to support IAS Analysts in performing interactive analyses during anomaly investigation.

IDL's features include: image processing, interactive 2D and 3D graphics, insightful volume visualization, a high-level programming language, integrated mathematics and statistics, flexible data I/O, a cross-platform GUI toolkit, and program linking tools.

Complete information on the IDL package can be obtained from the RSI World Wide Web (WWW) site using the Uniform Resource Locator (URL):

http://www.rsinc.com

4.2.4 The Environment for Visualizing Imagery (ENVI)

The Environment for Visualizing Imagery (ENVI) from Better Solutions Consulting is a full-featured, general purpose COTS image processing system built on top of IDL. ENVI is designed to provide turn-key capabilities for panchromatic, multispectral, and hyperspectral analysis of satellite and aircraft remotely sensed data. ENVI has been selected to provide some of the functionality required for the Evaluation and Analysis subsystem and to support IAS Analysts in performing interactive analyses during anomaly investigation.

ENVI provides many classes of tools for image processing and manipulation. These include tools for: Integral Spectral Viewing and Analysis, Flexible Region-of-Interest

(ROI) and Masking Capabilities, Image Statistics, Interactive Histograms and Contrast Enhancements, Dynamic Interactive Scatter Plots, Band and File Math (flexible math operations using IDL functions and procedures), Interactive Spatial and Spectral Subsetting, Data Type and Storage Order Conversions, Vector conversion utilities, Standard and User Customized Map Projection Support, Data Transformations, Spatial- and Frequency-Domain Filtering, Supervised and Unsupervised Classification, Registration and Geometric Corrections, Image Mosaicking, Flexible Point and Click Image Annotation, Custom User-Function Interface, and Advanced Spectral Library and Hyperspectral Analysis Tools

Complete information on ENVI can be obtained from the ENVI World Wide Web (WWW) site using the Uniform Resource Locator (URL):

http://www.envi-sw.com

4.2.5 Web Browser

A commercial Web Browser will be used for browsing the EDC DAAC holdings. This capability will be augmented by ECS capabilities identified below.

4.2.6 IAS Software Development Environment

The IAS software development environment includes an ANSI-compliant C compiler, a debugger, and a *Power C Analyzer (PCA*) from SGI. The PCA will be used to analyze the opportunities for parallel programming. In addition, *Purify* and possibly other tools will be used to validate source code and to analyze memory leak problems. IAS software configuration management will be accomplished using PVCS.

4.3 IAS NDI Software

The IAS will use software developed by the Hughes Information Technology Company (HITC) under the EOSDIS Core System (ECS) contract for interfacing with the EDC DAAC. Specific applications to be used are the Earth Science Search Tool (ESST) and Product Request Tool (PRT) clients and the ECS Ingest GUI. It is currently unclear whether these applications execute on the IAS Operations System or remotely on EDC DAAC servers.

The Earth Science Search Tool provides the means for finding, examining, and ordering Landsat-7 data granules from the Earth Science Data Collection located in the EDC DAAC. Capabilities are provided for: 1) entering search parameters and submitting them, 2) reviewing the results returned from the ECS database, and 3) selecting specific results for shipment to the client. for use in browsing the Landsat-7 holdings of the EDC DAAC. The Product Request Tool is an extension of the ESST that allows users to submit an order for selected data to the DAAC.

EOS HDF Tools are required for formatting IAS outputs that are ingested by ECS into the internal EOS HDF format.

The ECS Ingest GUI is used for transmitting IAS products to the EDC DAAC. The ECS Ingest GUI is used to complete an ECS network ingest request form, which creates a standard Delivery Record. The Delivery Record, which serves as a Data Availability Notice for ingesting IAS products, is submitted to the EDC DAAC using http.

Section 5. Operations Design

Presented below are scenarios that describe how the IAS design will support operations.

Order Data from DAAC

The user brings up a Web Browser and connects to the DAAC Web server. Using the available searchable meta-data for Landsat 7 scenes the user browses the archive for scene data to order. Once a desired scene has been identified the user places an order for the data by filling out a DAAC order form. If the data is being ordered to fill a request for a Work Order then using “cut and paste” operations the user puts the scene id into the scene id field of the Work Order in the Work Order Setup form of the User Interface (UI).

Once the DAAC has notified the IAS that the requested data is available the IAS retrieves the data and moves it to the appropriate location in the IAS storage system. The data is checked for correctness and completeness and then entered into the IAS database as having been received. The database is checked for Work Orders waiting on the data and those Work Orders for which data has arrived are updated to indicate the data is now available. The operator is notified of any data files for which no corresponding Work Order can be found.

Generate MOC Request

The user brings up the Generate MOC Request display to create either a concentrated ephemeris request or a calibration scene request for transfer to the MOC.

For the concentrated ephemeris request the user specifies either the start and end times for the time span or the user may select a cataloged L0R product and have the system extract the start and end times to use from the specified L0R product. Multiple ephemeris requests may be included in a single request file. Once the user has finished building requests the request file is created and staged to the transfer area. Information about concentrated ephemeris requests is logged to the database for tracking purposes.

There are two types of calibration scene requests; orbit number based and WRS path/row based. The user specifies which type is to be generated and fills in the appropriate information in the request display. Multiple calibration scene requests may be included in a single request file. Each calibration scene request is logged to the database so that the user will have the appropriate information available for a later search of the DAAC for the resulting L0R product. Once the user has finished building requests the request file is created and staged to the transfer area.

Setup Work Order

The user brings up the Work Order Setup display in the UI to define a new Work Order or to modify an existing Work Order.

For a new Work Order the system will display an entry form with input fields for the user to specify the type of request, the L0R input file(s), the date/time the input files were requested, named procedure to be applied to the input files, the desired completion date, the Work Order priority, and a comment field. List of values for fields are provided where appropriate.

A named procedure consists of a set of one or more named scripts. These named scripts contain commands that effect the processing of the L0R data. Each named script has a set of possible input parameters. Default values are supplied for all input parameters. The user may change any of the input parameters at the time of Work Order creation. One of the parameters associated with a named script is the action to take on the completion of the script. The user may specify the action as *continue*, meaning to continue with the following script, or as *stop*, meaning to stop at this point to allow a user to examine results or to perform interactive tasks. A stopped Work Order is resumed by changing its state to *continue*.

The user also uses the Work Order Setup display to modify an existing Work Order. For existing Work Orders the current values of all Work Order parameters are displayed. Depending on the current state of the Work Order the user will be allowed to modify certain parameters (e.g. resume a stopped Work Order).

Once the Work Order setup/modification has been completed the user commits the entry to the database and it is then ready to be considered by the Control Processing function for submission to the system for processing.

Anomaly Resolution and “What if” Scenarios

IAS users have the capability to perform processing tasks in a “local” environment such that the results from this processing do not “contaminate” the results obtained from the normal IAS processing flow. This “local” environment is used for anomaly resolution and for running “what if” processing scenarios. Users may insert test versions of programs into the processing flow and experiment with various parameter settings. Users have the same user interface capabilities and will have access to the same data products and programs in their “local” environment as are available in the normal IAS processing environment. Processing within this “local” environment may take place on the users workstation or can be directed to run on the main IAS processor on a non-interference basis.

Generate Calibration Parameter File

The result of Work Order processing is a set of data that are used in the construction of calibration parameters. A calibration parameter set, derived from the results of Work Order processing, is stored in the database and may be refined by the IAS analysts. The IAS will periodically (at least once every 90 days) generate a new Calibration Parameter File.

Once the decision has been made to generate a new calibration parameter file the user brings up the Generate Calibration Parameter File display to enter the required information. The user specifies the id of the calibration parameter set to extract from the database and the output directory area in which to create the file. The calibration parameter set is flagged to indicate that a Calibration Parameter File has been generated using this data The system constructs the appropriate filename and creates the file in the specified output directory. After the file has been created it is reviewed and quality checked by IAS personnel before being approved and promoted to the staging area for distribution.

The user brings up a web browser display and connects to the DAAC web server in order to fill out a data availability notice informing the DAAC to retrieve the new calibration parameter file from the IAS. The user also initiates an ftp transfer of the calibration parameter file to the the MOC.

Appendix A. Requirements Allocation Matrix

The following table contains the Landsat 7 Requirements Allocation Matrix.

Reqt Number	Requirement Statement	PCS	DMS	E&A	RPS	GPS	HW	Op
3.2.1.1.1	The IAS shall interface with the EDC DAAC for purposes of searching for and ordering of data from the Landsat 7 archive.	X						
3.2.1.1.2	The IAS shall receive Level 0R data, Level 0R products, and associated ancillary data from the EDC DAAC.		X					
3.2.1.1.3	The IAS shall interface with the EDC DAAC to coordinate the transfer of calibration parameter files and IAS-generated reports.							X
3.2.1.1.4	The IAS shall send calibration parameter files and IAS-generated reports to the EDC DAAC.		X					
3.2.1.2.1	The IAS shall interface with the LPS to coordinate the transfer of calibration parameter files and reprocessing requests.							X
3.2.1.2.2	The IAS shall send reprocessing requests to the LPS.							X
3.2.1.2.3	The IAS shall receive disposition of reprocessing requests from the LPS.							X
3.2.1.2.4	The IAS shall send calibration parameter files to the LPS.		X					
3.2.1.3.1	The IAS shall send requests to the MOC for the operational acquisition of partial-aperture calibration data, full-aperture calibration data, and surface image data of radiometric and geometric calibration ground sites.	X						
3.2.1.3.2	The IAS shall coordinate with the MOC for the acquisition of ETM+ imagery required for calibration and image assessment, for the transfer of calibration parameter files, and for the transfer of problem reports.							X
3.2.1.3.3	The IAS shall send requests to the MOC for concentrated definitive ephemeris.	X						
3.2.1.3.4	The IAS shall send problem reports to the MOC.		X					
3.2.1.3.5	The IAS shall send calibration parameter files to the MOC.		X					
3.2.1.3.6	The IAS shall be capable of receiving telemetry trend reports, spacecraft status reports, and event schedules from the MOC.		X					
3.2.1.3.7	The IAS shall be capable of receiving Flight Dynamics Facility (FDF)-generated, definitive ephemeris from the MOC.		X					
3.2.1.4.1	The IAS shall send problem reports and summary reports to the MMO.							X
3.2.2.1.1	The IAS shall be able to use data from the internal calibrator in the calibration of the radiometric response of each ETM+ detector.				X			
3.2.2.1.2	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the partial-aperture solar calibrator (PASC).				X			
3.2.2.1.3	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the full-aperture solar calibrator (FASC).				X			

Reqt Number	Requirement Statement	PCS	DMS	E&A	RPS	GPS	HW	Op
3.2.2.1.3	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the full-aperture solar calibrator (FASC).				X			
3.2.2.1.4	The IAS shall be able to calibrate the radiometric response of each ETM+ detector given Level 0R data of a ground calibration site and corresponding at-aperture spectral radiance values.				X			
3.2.2.1.5	The IAS shall be able to calibrate the radiometric response of each ETM+ detector using Level 0R data from preship and prelaunch calibration sources and auxiliary calibration source data.				X			
3.2.2.1.6	The IAS shall have the capability of assessing the short-term and long-term stability of the onboard calibration sources, which include the FASC, the PASC, and the internal calibrators.				X			
3.2.2.1.7	The IAS shall be able to integrate the results of the various calibration processes into an optimal estimate of radiometric calibration of each detector (except band 6) and provide new calibration parameters.				X			
3.2.2.1.8	The IAS shall be capable of generating radiometric calibration updates for the calibration parameter file.				X			
3.2.2.1.9	The IAS shall be able to transfer the calibration of each detector to the internal calibrator.				X			
3.2.2.2.1	The IAS shall be capable of determining the misalignment between the satellite navigational base reference and the ETM+ payload line-of-sight (LOS).					X		
3.2.2.2.2	The IAS shall be capable of determining band-to-band registration parameters.					X		
3.2.2.2.3	The IAS shall be capable of characterizing and updating along and across scan parameters (i.e., scan mirror profiles, scan-line corrector mirror profile, detector offsets, detector delays).					X		
3.2.2.2.4	The IAS shall be capable of generating geometric calibration updates for the calibration parameter file.					X		
3.2.2.3.1	The IAS shall be capable of processing payload correction data (PCD) data to correct spacecraft time, generate a sensor pointing model (attitude and jitter), and calculate spacecraft position and velocity (ephemeris).		X			X		
3.2.2.3.2	The IAS shall be capable of processing ETM+ Level 0R products to produce radiometrically corrected Level 1R image data.				X			
3.2.2.3.3	The IAS shall be capable of creating systematically corrected ETM+ Level 1G imagery from Level 0R products.				X	X		
3.2.2.3.4	The IAS shall be capable of creating precision corrected ETM+ Level 1G imagery from Level 0R products and ground control points (GCPs).				X	X		
3.2.2.3.5	The IAS shall be capable of creating terrain corrected ETM+ Level 1G imagery from Level 0R products, GCPs, and elevation data.				X	X		
3.2.2.3.6	The IAS shall be capable of performing image-to-image registration.					X		
3.2.2.3.7	The IAS shall be capable of incorporating IAS-generated calibration coefficient updates to generate Level 1 data.				X	X		
3.2.2.3.8	The IAS shall support nearest neighbor, cubic convolution, and modulation transfer function (MTF) compensation resampling.					X		
3.2.2.3.9	The IAS shall have the capability to produce a 1G product with a grid cell size that is variable from 15 to 60 meters, in increments of 1 millimeter (mm).					X		

Reqt Number	Requirement Statement	PCS	DMS	E&A	RPS	GPS	HW	Op
3.2.2.3.10	The IAS shall have the capability to map project 1G using the Space Oblique Mercator, Universal Transverse Mercator, Lambert Conformal Conic, Transverse Mercator, Oblique Mercator, and Polyconic coordinate reference systems.					X		
3.2.2.3.11	The IAS shall have the capability to create a 1G image oriented to nominal path or north-up.					X		
3.2.2.3.12	The IAS shall be capable of processing Mirror Scan Correction Data (MSCD) to generate scan mirror and scan line corrector mirror models.					X		
3.2.2.3.13	The IAS shall be capable of compensating for inoperable and saturated detectors during Level 1R and 1G processing.				X			
3.2.2.3.14	The IAS shall be capable of compensating for the image artifacts of striping, banding, coherent noise, memory effect, and scan correlated shift in Level 1R and 1G processing.				X			
3.2.2.3.15	The IAS shall be capable of processing to Level 1R and 1G both ascending and descending pass ETM+ Level 0R data.				X	X		
3.2.2.4.1	The IAS shall evaluate the on-orbit operability of ETM+ detectors.				X			
3.2.2.4.2	The IAS shall be able to evaluate the absolute radiometric accuracy of ETM+ Level 0R, 1R, and 1G data.				X			
3.2.2.4.3	The IAS shall be able to assess the identified ETM+ radiometric image artifacts of striping; banding; random, correlated, and coherent noise; memory effect; and scan-correlated shift.				X			
3.2.2.4.4	The IAS shall be able to evaluate the MTF of each ETM+ detector.				X			
3.2.2.4.5	The IAS shall be able to evaluate the signal-to-noise ratio (SNR) of each ETM+ detector, using prelaunch and on-orbit image data.				X			
3.2.2.4.6	The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector with respect to dynamic range.				X			
3.2.2.4.7	The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector, excluding band 6, with respect to linearity (TBD).				X			
3.2.2.4.8	The IAS shall be able to evaluate the geodetic accuracy of ETM+ Level 1G image data.					X		
3.2.2.4.9	The IAS shall be able to evaluate the internal geometric accuracy of ETM+ Level 1G image data.					X		
3.2.2.4.10	The IAS shall be able to evaluate the band-to-band registration accuracy of ETM+ imagery.					X		
3.2.2.4.11	The IAS shall be able to evaluate the image-to-image registration accuracy of ETM+ data.					X		

Reqt Number	Requirement Statement	PCS	DMS	E&A	RPS	GPS	HW	Op
3.2.2.4.12	The IAS shall be able to evaluate the quality of Level 0R products. Quality checks will include but not be limited to those listed in Table 3.2.2.4-1.		X		X			
3.2.2.4.12a	The IAS shall provide the capability to visually check L0R Product imagery.			X				
3.2.2.4.12b	The IAS shall range check all but the housekeeping parameters in the L0R Product Payload Correction Data.		X					
3.2.2.4.12c	The IAS shall validate scan direction consistency in the L0R Product Mirror Scan Correction Data.		X					
3.2.2.4.12d	The IAS shall validate FHSERR/SHSERR consistency in the L0R Product Mirror Scan Correction Data.		X					
3.2.2.4.12e	The IAS shall validate counted line length consistency in the L0R Product Mirror Scan Correction Data.		X					
3.2.2.4.12f	The IAS shall validate dropped line locations in the L0R Product Mirror Scan Correction Data.				X			
3.2.2.4.12g	The IAS shall validate the consistency of the applicability date in the Calibration Parameter File with the L0R Product image files.		X					
3.2.2.4.12h	The IAS shall validate the consistency of the Calibration Parameter File of the L0R Product with the IAS database.		X					
3.2.2.4.12I	The IAS shall support validation of ACCA scores from the L0R Product metadata through visual inspection of the associated L0R image files.			X				
3.2.2.4.12j	The IAS shall validate scene coordinates from the L0R Product metadata.		X					
3.2.2.4.12k	The IAS shall validate file name consistency from the L0R Product metadata.		X					
3.2.2.4.12l	The IAS shall validate the correctness of WRS scene parameters from the L0R Product metadata.		X					
3.2.2.4.12m	The IAS shall validate calibration outliers in the L0R Product Calibration Pulse/Shutter data.				X			
3.2.2.4.12n	The IAS shall validate shutter means in the L0R Product Calibration Pulse/Shutter data.				X			
3.2.2.4.12o	The IAS shall validate shutter standard deviations in the L0R Product Calibration Pulse/Shutter data.				X			
3.2.2.4.12p	The IAS shall validate shutter outliers in the L0R Product Calibration Pulse/Shutter data.				X			
3.2.2.4.13	The IAS shall be capable of performing a trend analysis over any desired time interval for each selected evaluation activity.			X				
3.2.2.4.15	The IAS shall provide the capability to visually inspect image data.			X				
3.2.2.4.16	The IAS shall provide a capability that allows an image analyst to monitor assessment processes and results.			X				

Reqt Number	Requirement Statement	PCS	DMS	E&A	RPS	GPS	HW	Op
3.2.2.4.17	The IAS shall have the capability to review output data, including but not limited to calibration reports and updates.			X				
3.2.2.5.1	The IAS shall have the capability to acquire, develop, test, and add new algorithms and software to improve the radiometric and geometric properties of ETM+ data and their assessment without impacting IAS operations.	X					X	X
3.2.2.5.2	The IAS shall support the development of algorithms to remove image artifacts and detector outages from Level 1R and 1G data without impacting normal IAS operations.						X	X
3.2.2.5.3	The IAS shall have the capability to incorporate new algorithms into the operational system without impacting normal IAS operations.	X						X
3.2.2.5.4	The IAS shall maintain configuration control of all algorithms, databases, software, and hardware used in operations.							X
3.2.2.6.1	The IAS shall provide the capability to select the processing to be applied to data sets.	X						
3.2.2.6.2	The IAS shall be capable of archiving all software and databases used in operations.		X					
3.2.2.6.3	The IAS shall be capable of storing selected data, parameters, ancillary data, reports, and documents.		X					
3.2.2.6.4	The IAS shall have the ability to monitor and control processes.	X						
3.2.2.6.5	The IAS shall be capable of storing selected GCPs and GCP chips.					X		
3.2.2.6.6	The IAS shall be capable of storing selected digital elevation models (DEMs).					X		
3.2.2.6.7	Deleted.							
3.2.2.6.8	The IAS shall be capable of storing solar spectral and broadband radiance data.				X			
3.2.2.6.9	The IAS shall have the capability to write outputs to tape.		X				X	
3.2.2.6.10	The IAS shall have the capability to generate hardcopy outputs.	X		X			X	
3.2.2.6.11	The IAS shall archive selected prelaunch data, including but not limited to sensor engineering, ETM+ image data, alignment matrices, calibration measurements, mirror scan profiles, FASC bi-directional reflectance distribution function (BRDF), etc.				X	X		
3.2.2.6.12	The IAS shall allow the operator to select thresholds for results and errors reported by the IAS.	X						
3.2.2.6.13	The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.	X	X	X	X	X		
3.2.2.7.1	The IAS shall generate calibration, data quality assessment, and problem reports.		X	X	X	X		
3.2.2.7.2	The IAS shall be capable of generating metadata for all reports sent to the EDC DAAC Guide Server.		X					

Reqt Number	Requirement Statement	PCS	DM S	E&A	RPS	GP S	HW	Op
3.2.2.7.3	The IAS shall generate annual reports that document calibration coefficient and performance analysis trends.			X				
3.2.2.7.4	The IAS shall generate reports of anomaly detection analyses as they are concluded.			X				
3.2.2.7.5	The IAS shall generate processing summaries after each IAS activity.	X	X		X	X		
3.2.3.1	The IAS shall be capable of calibrating the radiometric response (absolute spectral radiance) of each operable ETM+ detector to an accuracy of 5 percent, 1 sigma, providing all inputs are within specification.				X			
3.2.3.2	The IAS shall be capable of calibrating the relative radiometric response such that the ratio of ETM+ equivalent at-aperture radiances between any combination of two spectral bands, excluding band 6, shall vary less than 2 percent, 1 sigma, over a 7-day p				X			
3.2.3.3	The IAS shall contribute no greater than 0.7 percent uncertainty to absolute radiometric accuracy during the generation of Level 1R and 1G data.				X	X		
3.2.3.4	The IAS shall be able to create systematic imagery to a geodetic accuracy of 250 meters, 1 sigma, providing all inputs are within specification. Performance applies to along-track and cross-track directions and is referenced to a nadir-viewing geometry.					X		
3.2.3.5	The IAS shall contribute circular errors no greater than 1.8 meters, 1 sigma, in the production of systematically corrected ETM+ Level 1G imagery. This error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.					X		
3.2.3.6	The IAS shall provide the capability to register pixels from a band to the corresponding pixels of the other bands in a common scene to an accuracy of 0.28 sensor guide star data (GSD), 0.9p, in along-track and cross-track directions, providing all inputs					X		
3.2.3.7	The IAS shall contribute error no greater than 0.11 multispectral sensor GSD, 0.9p, along-track, and 0.24 multispectral sensor GSD, 0.9p, cross-track, in the assessment of band-to-band registration.					X		
3.2.3.8	The IAS shall provide the capability to perform image-to-image registration to an accuracy of 0.4 multispectral sensor GSD, 0.9p, in the along-track and cross-track directions providing all inputs are within specification.					X		
3.2.3.9	The IAS shall contribute circular errors no greater than 3.6 meters, 1 sigma, during image-to-image registration correction of ETM+ Level 1G data. Error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.					X		
3.2.3.10	The IAS shall be capable of estimating the field angles to an accuracy of 0.18 arcsec, 1 sigma.					X		
3.2.3.11	The IAS shall be capable of digitally correlating common features in separate bands of the same image or same bands of separate images to an accuracy of 0.1 pixel, 0.9p.					X		

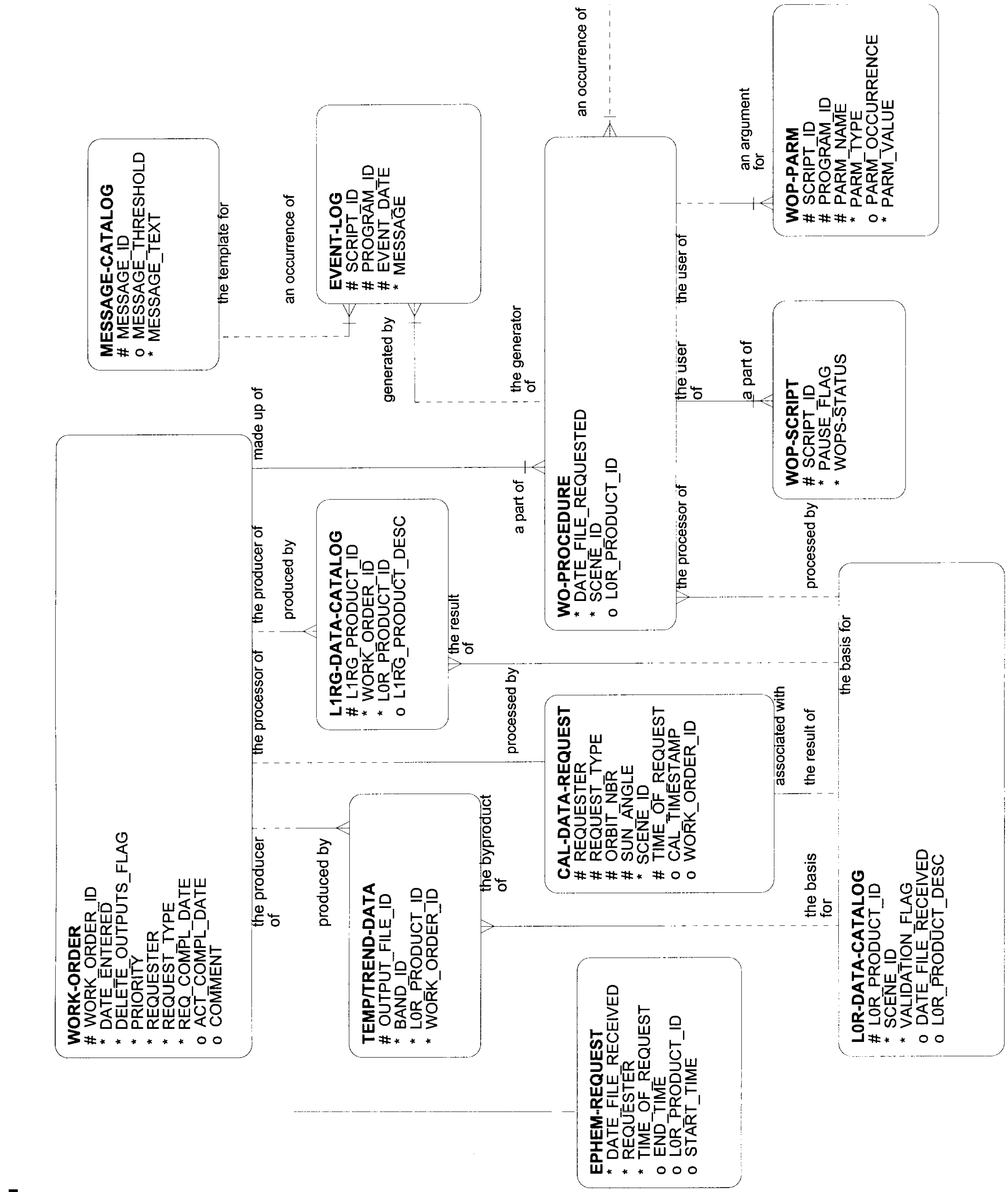
Reqt Number	Requirement Statement	PCS	DMS	E&A	RPS	GPS	HW	Op
3.2.3.12	The IAS shall be capable of estimating the alignment of the ETM+ line-of-sight to the satellite navigation base reference to an accuracy of 24 arcsec, 1 sigma, in all axes.					X		
3.2.3.13	Deleted.							
3.2.3.14	The IAS shall be capable of generating the equivalent of up to 10 ETM+ Level 1G systematically corrected scenes in a 24-hour day over the life of the mission. (NOTE: This requirement is meant to size the maximum capacity of the system.)						X	
3.2.3.15	The IAS shall be capable of receiving and storing 10 ETM+ Level 0R scene products or equivalent per day of data from the EDC DAAC.		X				X	
3.2.3.16	The IAS shall be capable of archiving test site image data (initial, intermediate, and final products), characterization data, calibration data, calibration parameter files, and reports, generated by the IAS, over the life of the mission.		X				X	
3.2.3.17	The IAS shall generate monthly reports that document the quality of 0R data and 0R products retrieved from the EDC DAAC.			X				
3.2.3.18	The IAS shall provide regular calibration and performance updates to the EDC DAAC and other interfaces quarterly.		X	X				
3.2.3.19	The IAS shall provide an annual Landsat 7 image quality report.			X				
3.2.3.20	The IAS shall have an on-line data storage capacity of 100 gigabytes (GB) (TBR) for image data.		X				X	
3.2.3.21	The IAS shall be capable of storing 68 megabytes (MB) of GCP data (points, chips, metadata).					X	X	
3.2.3.22	The IAS shall capable of storing 20 GB of elevation data.					X	X	
3.2.4.1	Deleted.							
3.2.4.2	The IAS shall support end-to-end testing at least 12 (TBR) months before launch.							X
3.2.4.3	The IAS shall be capable of supporting full operations at launch -6 months.							X
3.2.4.4	The IAS shall support mission operations for a minimum of 5 years following in-orbit checkout (IOC).							X
3.2.4.5	The IAS shall operate two shifts for 7 days a week during IOC plus 48 days (TBR).							X
3.2.4.6	The IAS shall be staffed during prime shift post-IOC plus 48 days (TBR).							X
3.2.4.7	The IAS shall ensure backup of all on-line data and operations software.		X					
3.2.4.8	The IAS shall perform calibrations, assessments, and evaluations with frequencies specified in Tables 3.2.4-1 and 3.2.4-2.		X	X	X	X		
3.2.4.8a	The IAS shall perform sensor alignment calibrations calibrations.					X		
3.2.4.8b	The IAS shall perform band-to-band registrations.					X		
3.2.4.8c	The IAS shall perform detector delay calibrations.					X		
3.2.4.8d	The IAS shall perform radiometric calibrations.				X			
3.2.4.8e	The IAS shall generate calibration reports quarterly.			X				
3.2.4.8f	The IAS shall perform detector operability assessments.				X			
3.2.4.8g	The IAS shall perform radiometric accuracy assessments.				X			
3.2.4.8h	The IAS shall perform streaking and banding assessments.				X			

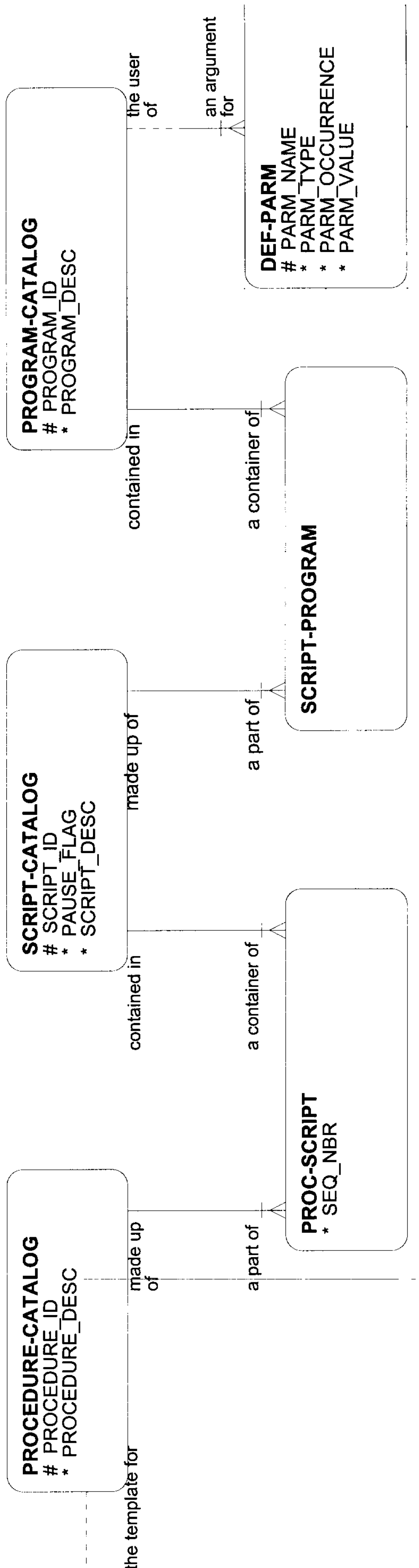
Reqt Number	Requirement Statement	PCS	DMS	E&A	RPS	GPS	HW	Op
3.2.4.8i	The IAS shall perform correlated and coherent noise assessments.				X			
3.2.4.8j	The IAS shall perform MTF assessments.				X			
3.2.4.8k	The IAS shall perform SNR assessments.				X			
3.2.4.8l	The IAS shall perform geodetic accuracy assessments.					X		
3.2.4.8m	The IAS shall perform geometric accuracy assessments.					X		
3.2.4.8n	The IAS shall perform Band-to-band registration accuracy.					X		
3.2.4.8o	The IAS shall perform Image-to-image registration accuracy.					X		
3.2.4.8p	The IAS shall perform Image artifact assessments.				X			
3.2.4.8q	The IAS shall generate assessment reports quarterly.			X				
3.2.4.8r	The IAS shall evaluate LPS data quality.		X					
3.2.4.8s	The IAS shall evaluate Level 0R data and products.		X		X	X		
3.2.4.8t	The IAS shall evaluate Level 1R data quality.				X			
3.2.4.8u	The IAS shall evaluate PCD quality.		X			X		
3.2.4.8 v	The IAS shall generate evaluation reports on a monthly, quarterly, and annual basis.			X				
3.2.4.8w	The IAS shall perform selected trend analyses.			X				
3.2.4.9	The IAS shall have the capability to maintain and upgrade all operational software.							X
3.2.4.10	The IAS shall be capable of supporting training without impacting daily work loads.						X	X
3.2.4.11	The IAS shall provide an operational availability of 0.85 (TBR) or better for all processing functions.						X	
3.2.4.12	The IAS shall support a mean-time-to-restore (MTTR) capability of 12 (TBR) hours or better.						X	X
3.2.4.13	The IAS shall be capable of retrieving cross-calibration data of other sensors from the EDC DAAC.	X						
3.2.4.14	The IAS capability shall be used in performing anomaly assessment, resolution, and reporting.			X				

Appendix B. Database Design

This section presents the system-level design for the IAS database. The design will evolve to incorporate the usage of the Oracle database by the radiometric and geometric algorithms once their descriptions are finalized and baselined. The detailed database design will be documented at the completion of the detailed design phase in the *IAS Database Design Specification.*

Figure B-1 presents the IAS Entity-Relationship Diagrams (ERDs).


MESSAGE-CATALOG
MESSAGE_ID
o MESSAGE_THRESHOLD
* MESSAGE_TEXT
the template for
an occurrence of
EVENT-LOG
SCRIPT_ID
PROGRAM_ID
EVENT_DATE
* MESSAGE
generated by
the generator of
an occurrence of
WO-PROCEDURE
* DATE_FILE_REQUESTED
* SCENE_ID
o L0R_PRODUCT_ID
the user of
the user of
a part of
an argument for
WOP-PARM
SCRIPT_ID
PROGRAM_ID
PARM_NAME
* PARM_TYPE
o PARM_OCCURRENCE
* PARM_VALUE
WOP-SCRIPT
SCRIPT_ID
* PAUSE_FLAG
* WOPS-STATUS
made up of
a part of
the processor of
processed by
WORK-ORDER
WORK_ORDER_ID
* DATE_ENTERED
* DELETE_OUTPUTS_FLAG
* PRIORITY
* REQUESTER
* REQUEST_TYPE
* REQ_COMPL_DATE
o ACT_COMPL_DATE
o COMMENT
the producer of
produced by
L1RG-DATA-CATALOG
L1RG_PRODUCT_ID
* WORK_ORDER_ID
* L0R_PRODUCT_ID
o L1RG_PRODUCT_DESC
the result of
the basis for
the processor of
processed by
CAL-DATA-REQUEST
REQUESTER
REQUEST_TYPE
ORBIT_NBR
SUN_ANGLE
* SCENE_ID
# TIME_OF_REQUEST
o CAL_TIMESTAMP
o WORK_ORDER_ID
associated with
the result of
the producer of
produced by
TEMP/TREND-DATA
OUTPUT_FILE_ID
* BAND_ID
* L0R_PRODUCT_ID
* WORK_ORDER_ID
the byproduct of
the basis for
L0R-DATA-CATALOG
L0R_PRODUCT_ID
* SCENE_ID
* VALIDATION_FLAG
o DATE_FILE_RECEIVED
o L0R_PRODUCT_DESC
EPHEM-REQUEST
* DATE_FILE_RECEIVED
* REQUESTER
* TIME_OF_REQUEST
o END_TIME
o L0R_PRODUCT_ID
o START_TIME


PROGRAM-CATALOG
PROGRAM_ID
* PROGRAM_DESC
the user of
an argument for
DEF-PARM
PARM_NAME
* PARM_TYPE
* PARM_OCCURRENCE
* PARM_VALUE
contained in
a container of
SCRIPT-PROGRAM
SCRIPT-CATALOG
SCRIPT_ID
* PAUSE_FLAG
* SCRIPT_DESC
made up of
a part of
contained in
a container of
PROC-SCRIPT
* SEQ_NBR
PROCEDURE-CATALOG
PROCEDURE_ID
* PROCEDURE_DESC
made up of
a part of
the template for

Entities and their Descriptions

Entity Name	Short Name	Description
CAL-DATA-REQUEST	CDR	Records calibration data requests entered by the user through the GUI.
DEF-PARM	DP	Contains the default parameters for the IAS application programs.
EPHEM-REQUEST	ER	Used to track requests for FDF ephemeris.
EVENT-LOG	EL	Contains a log of significant system events, e.g., alarms, alerts, etc.
L0R-DATA-CATALOG	L0R	Contains a catalog of L0R products.
L1RG-DATA-CATALOG	L1RG	Contains a catalog of L1R and L1G products that are the outputs from running a work order against a L0R image.
MESSAGE-CATALOG	MC	Contains a catalog of standard messages.
PROC-SCRIPT	PS	Provides a cross-reference between procedures and the script(s) they invoke.
PROCEDURE-CATALOG	PROC	Provides a catalog of standard (i.e., canned) procedures which can be selected for inclusion in a work order.

Entities and their Descriptions

Entity Name	Short Name	Description
PROGRAM-CATALOG	PGM	Contains a catalog of programs that may be included in scripts to be run as part of work orders.
SCRIPT-CATALOG	SC	Contains a catalog of standard (i.e., canned) scripts that can be included in a procedure.
SCRIPT-PROGRAM	SP	Provides a cross-reference between scripts and the programs they invoke.
TEMP/TREND-DATA	TT_DATA	Contains information about the output of a work order.
WO-PROCEDURE	WP	Provides a cross-reference between work orders, their procedures, and the L0R products they process.
WOP-PARM	WOPP	Identifies the actual (override?) parameters to be used by a program in a WO-Procedure.
WOP-SCRIPT	WS	Contains information about a script which is part of a work-order's procedure.
WORK-ORDER	WO	Contains information pertaining to a work order.

Appendix C. Standard Processing Flows

This section presents the Standard Processing Flows--the strings of algorithms to be executed--for the various image types that are planned to be acquired by the IAS. The specific flows, and their associated sections are as follows:

C.1 Day Scene Processing Flow

C.2 Night Scene Processing Flow

C.3 Partial Aperture Solar Calibrator (PASC) Scene Processing Flow

C.4 Full Aperture Solar Calibrator (FASC) Scene Processing Flow

C.5 Modulation Transfer Function (MTF) Scene Processing Flow

C.6 Focal Plane Calibration Processing Flow

C.7 Geodetic Test Site Scene Processing Flow

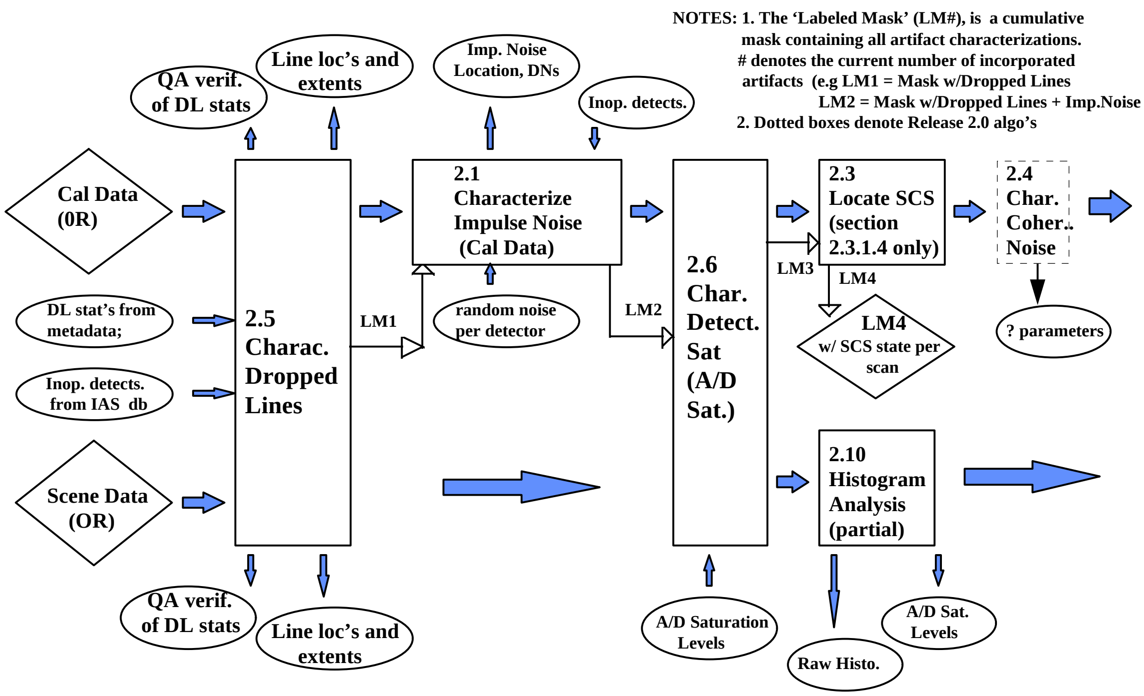
C.8 Geometric Super Site Scene Processing Flow

Table C-1 relates these flows to the assessments and calibrations that the IAS is required to perform. The table provides the number of scenes of various types that are to be acquired, as well as the number of these scenes that will be processed.

Table C-1.

Scene Type	# to order/ quarter	# to Process /Level	Assessments and Calibrations	Outputs/Reports
Random Day Scene	90	90 /1Gs	Level 0R Product Quality (Table 3.2.2.4-1) Detector Operability Detector Saturation Impulse and Random Noise Banding and Striping	Daily Assessment Report
Geodetic Test Site	6-24	(1) 12-48/1Gs	Geodetic Accuracy Sensor Alignment	Calibration Reports for each Quarterly Report/CPF Update
Geometric Super-Site	2-6	(2) 4-12/1Gt	Scan Mirror Calibration I-I Registration Assessment	Calibration Reports for each Quarterly Report/CPF Update
Focal Plane Cal. Image	4-12	4-12/1Gs	B-B Registration Assessment Band Placement Calibration	Calibration Reports for each Quarterly Report/CPF Update
Night Scenes	(3) 20-44	20-44/1R	Characterize Coherent Noise Char. Scan Correlated Shift Characterize Memory Effect	Assessment Report for each Quarterly Report
PASC Data	(4) 180	180/1Rp	Characterize Memory Effect Rel. Radiometric Accuracy	Calibration Report for each Quarterly Report/CPF update
FASC Data	(5) 8-30	8-30/1Rf	Characterize Coherent Noise Char. Scan Correlated Shift Characterize Memory Effect Rel. Radiometric Accuracy	Calibration Report for each Quarterly Report/CPF update
MTF Image			Characterize MTF	Assessment Report for each Quarterly Report/ CPF update
Ground Look Calibration	1	1/1Gt	Absolute Rad. Accuracy	Calibration Report

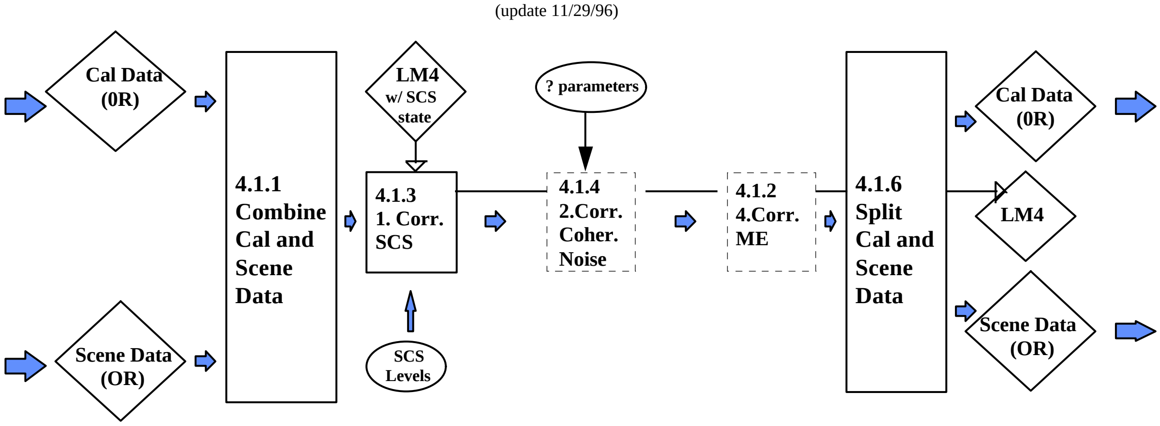
(1) For each of the 6-24 scenes, process PAN band once to 1G systematic using PCD ephemeris and once again using FDF definitive ephemeris for a range of 12-48.
(2) For each of the 2-6 scenes, process PAN band to 1G systematic and then to 1G terrain corrected.
(3) Optimally, a 20 scene interval is desired once per quarter. Additionally, the non-bright scenes acquired with the PASC images will be ordered 2 per week.
(4) PASC imaging is scheduled once per day, each PASC acquisition is approximately 6 scenes in length with the bright area of interest covering 2 scenes that will be ordered (90x2). Each scene will be processed to 1R level using a unique PASC processing algorithm.
(5) FASC imagaing is scheduled once every six weeks, therefore could be acquired once or twice in a quarter. There are two types of FASC imaging; one collecting 8 scenes when done in conjunction with PASC imaging and one collecting 15 images when done on a stand alone basis.



Level 1R Processing (Day Scene)
Release 1.0

Step 1. 0R Radiometric Characterization

(update 11/29/96)



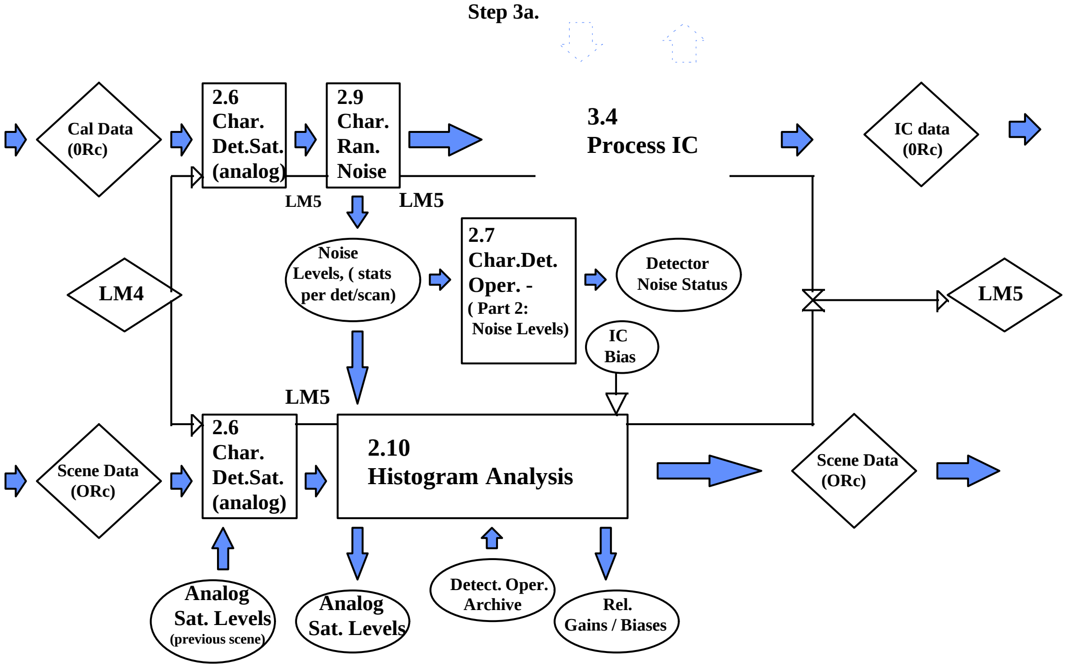
Note: Dotted boxes denote Release 2.0 algorithms

Level 1R Processing (Day Scene)
Release 1.0

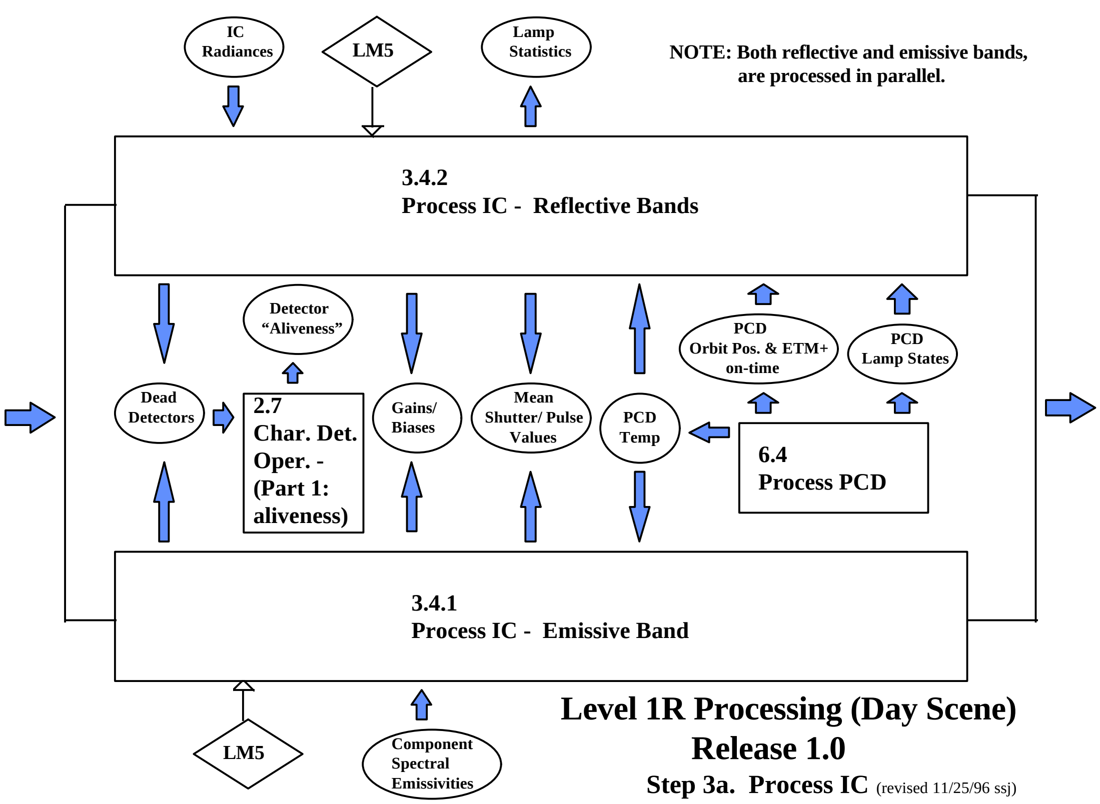
Step 2. Pre-1R Correction

(revised11/29/96 ssj)

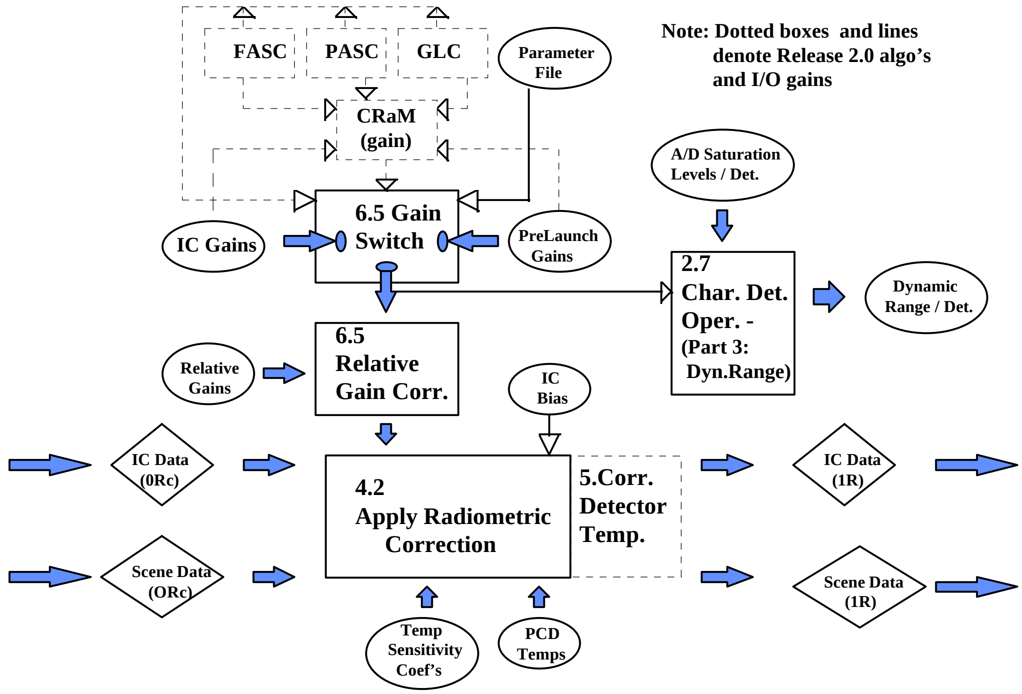
Notes: 1. Dotted boxes denote Release 2.0 algo's
2. For algorithm "3.4 Process IC", see detailed flow in Step 3a.



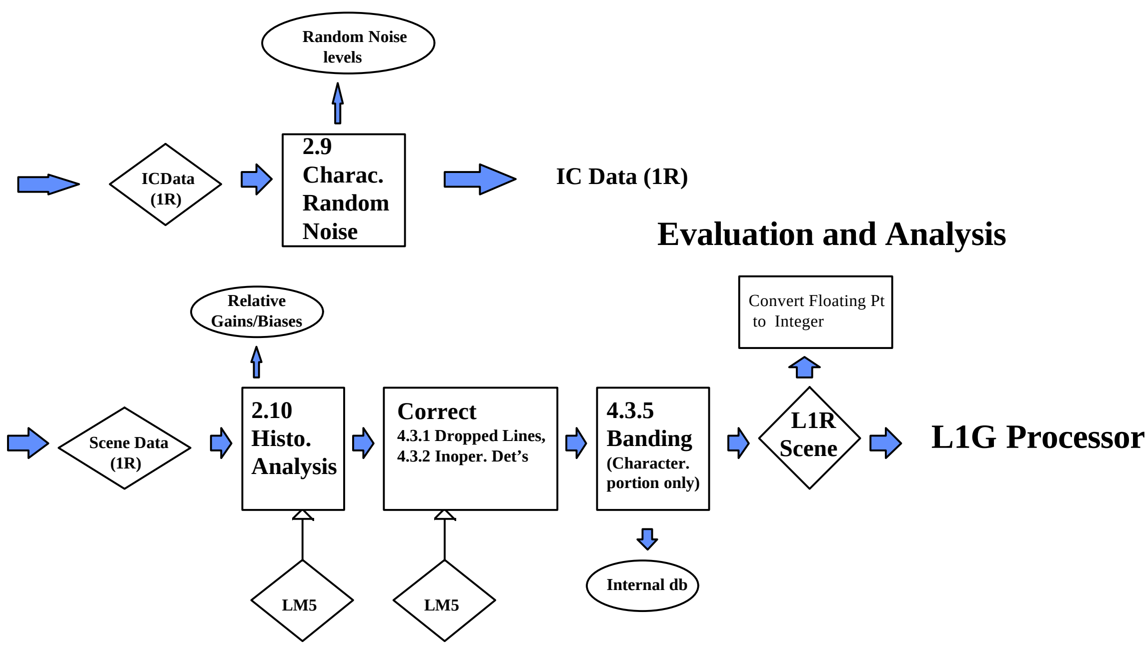
Level 1R Processing (Day Scene)
Release 1.0
Step 3. ORc Radiometric Characterization/Calibration
(revised 11/25/96 ssj)



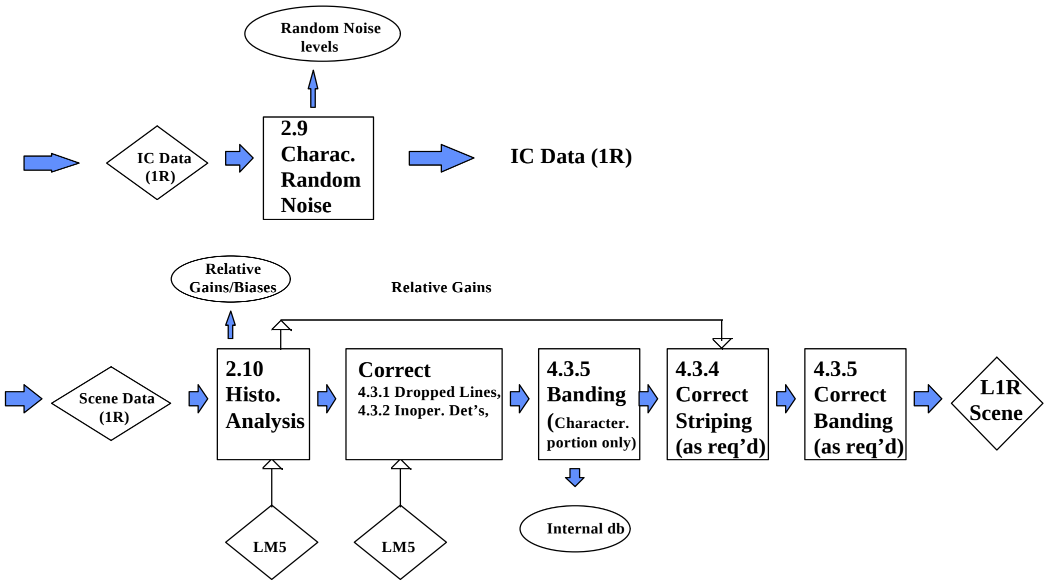
Level 1R Processing (Day Scene)
Release 1.0
Step 3a. Process IC (revised 11/25/96 ssj)



Level 1R Processing (Day Scene)
Release 1.0
Step 4. 1R Correction
(revised 9/11)



Level 1R Processing (Day Scene)
Release 1.0
Step 5.0 1R Radiometric Characterization/Correction
(Scenario 1: No Correction for Striping and Banding Effects)
(revised11/25/96)

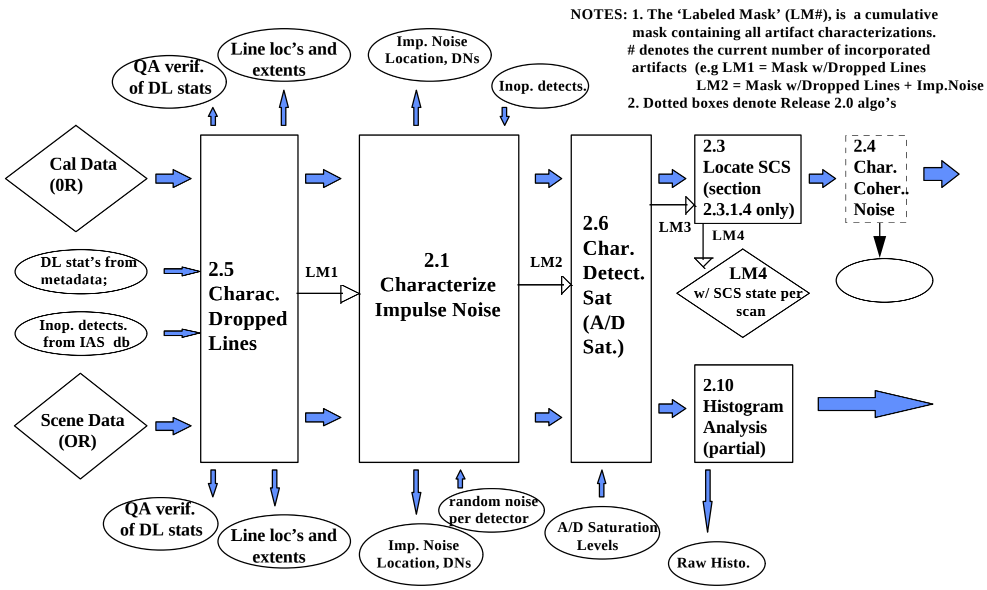


Level 1R Processing (Day Scene)
Release 1.0

Step 5.0 1R Radiometric Characterization/Correction

(Scenario 2: Correct for Striping and Banding Effects IFF Necessary)

(revised 11/25/96 ssj)

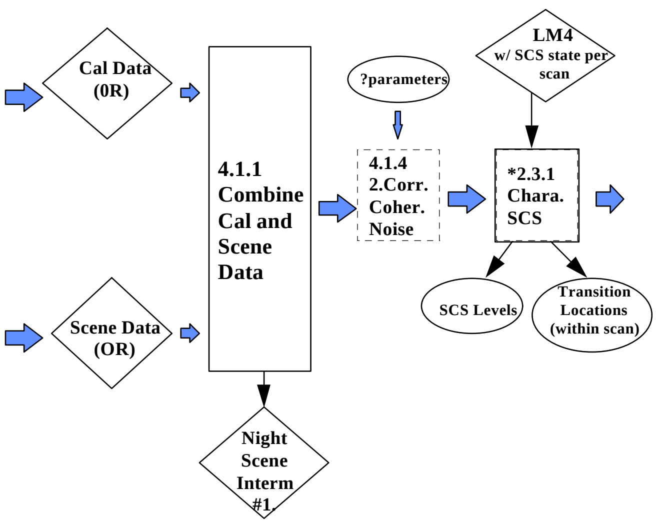


Process Night Scene

Step 1. 0R Radiometric Characterization

(update 11/29/96 ssj)

*** Not in Standard 1R processing**

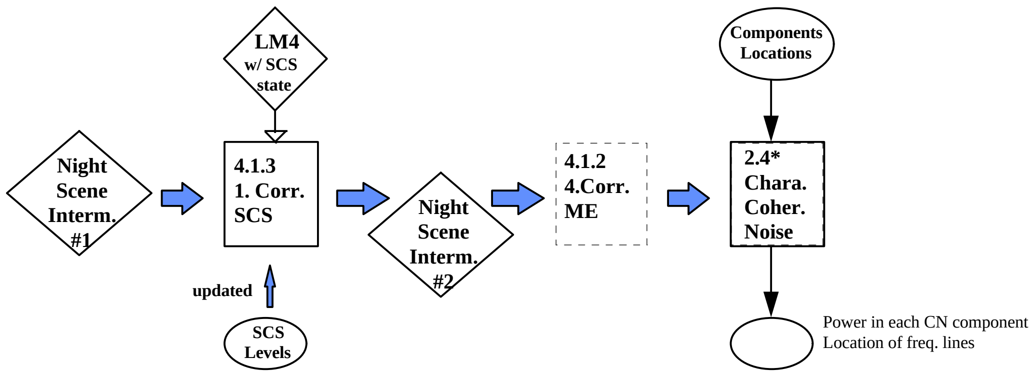


Process Night Scene

Step 2. Scan Correlated Shift Characterization

(revised 11/29/96 ssj)

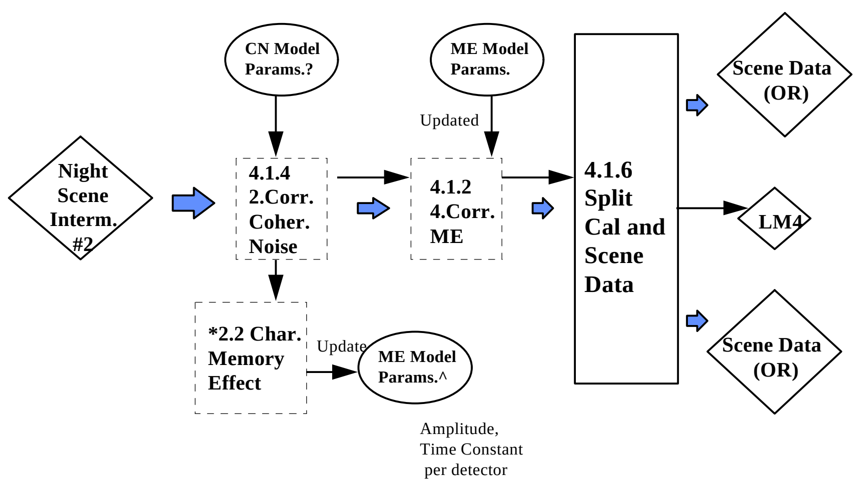
*** Not in Standard Level 1R Flow**



Process Night Scene

Step 3. Coherent Noise Characterization

(revised 11/29/96 ssj)



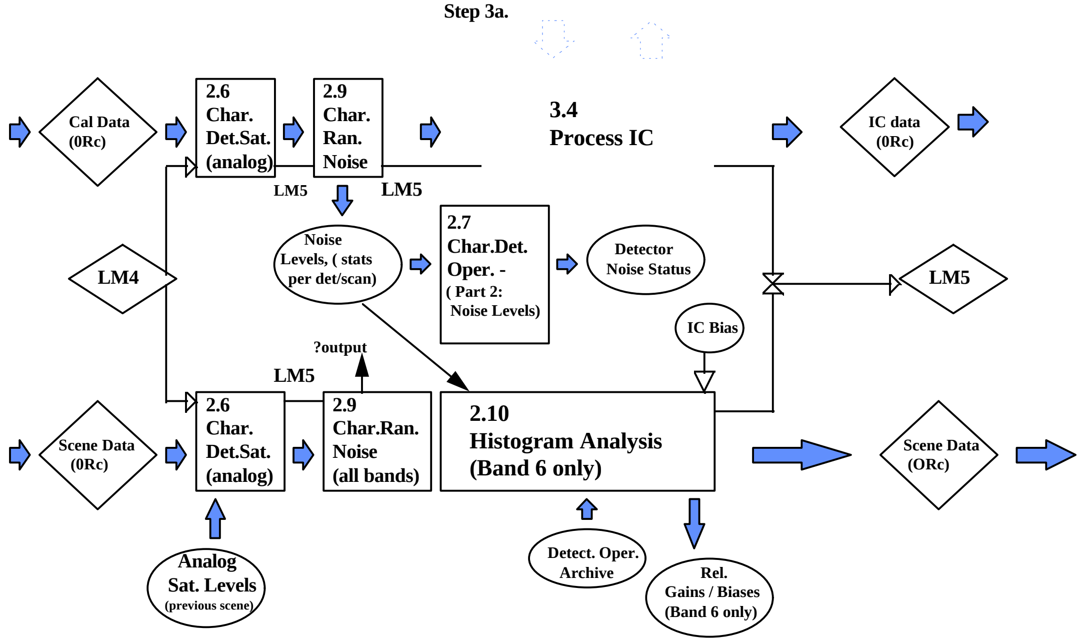
*** Not in Standard Level 1R Flow**
^ Saved separately by source (i.e. FASC, PASC, Night)

Process Night Scene

Step 4. Memory Effect Characterization

(revised 11/29/96 ssj)

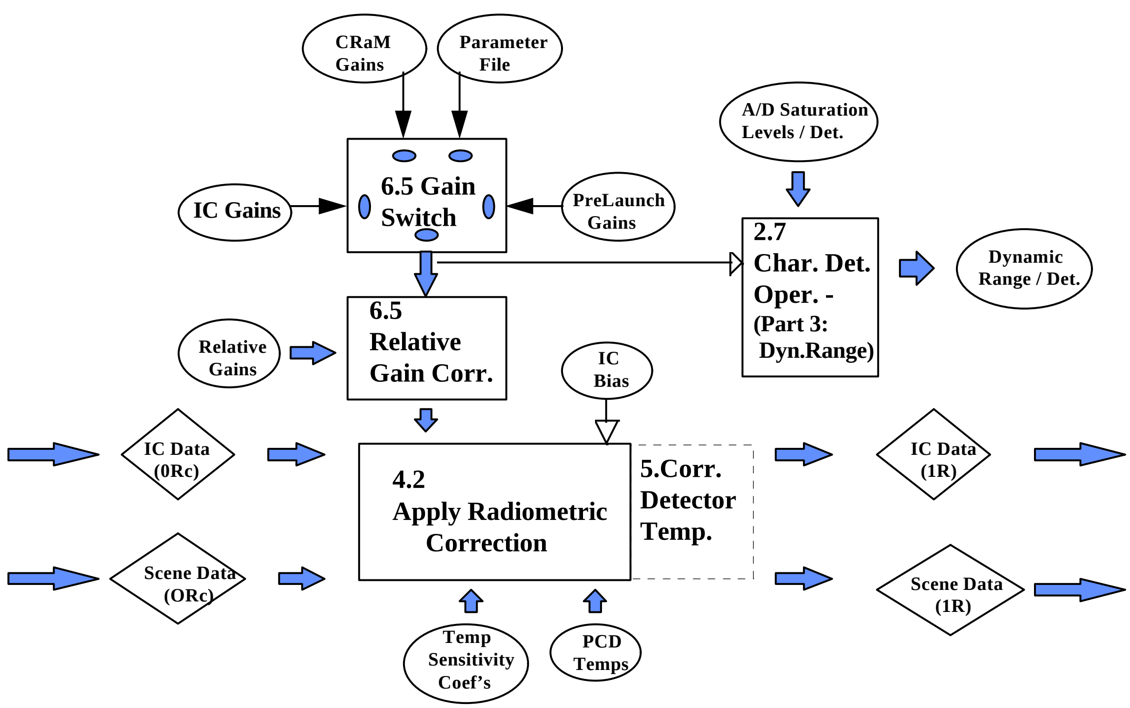
Notes: 1. Dotted boxes denote Release 2.0 algo's
2. For algorithm "3.4 Process IC", see detailed flow in Step 3a.



Processing Night Scene

Step 5. 0Rc Radiometric Characterization/Calibration

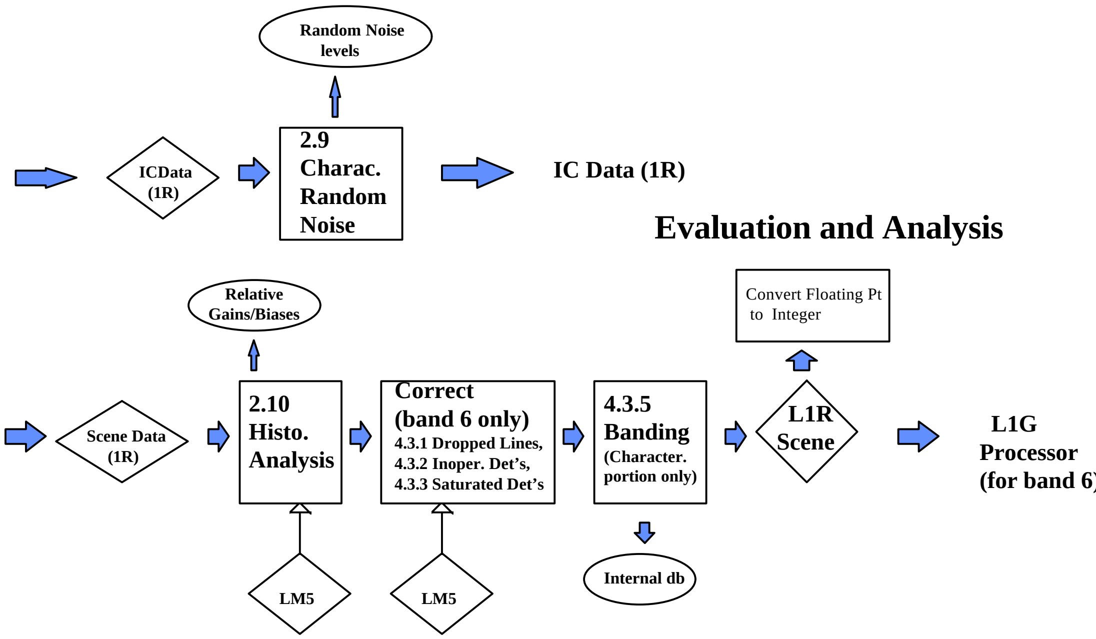
(revised 11/29/96 ssj)



Process Night Scene

Step 6. 1R Correction

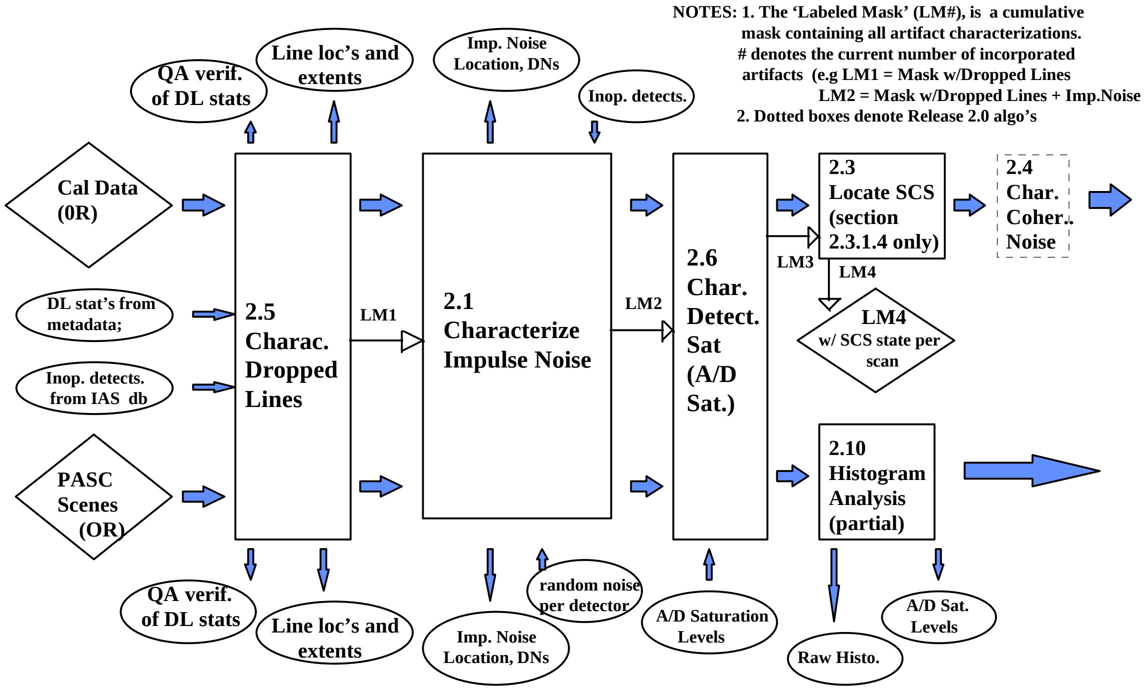
(revised 11/25/96 ssj)



Process Night Scene

Step 7. 1R Radiometric Characterization/Correction

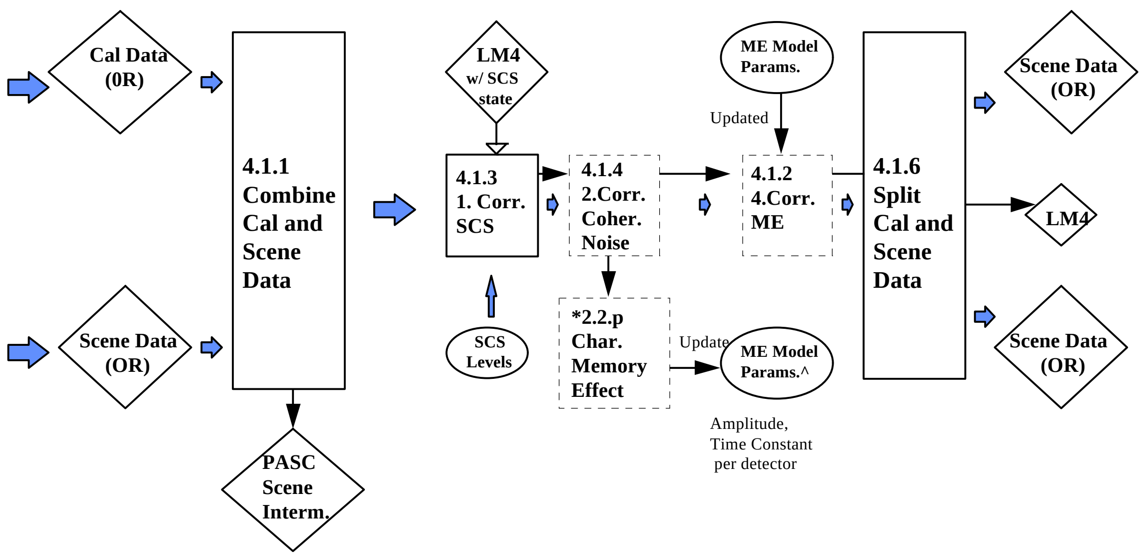
(revised11/29/96 ssj)



Process PASC

Step 1. 0R Radiometric Characterization

(update 11/29/96 ssj)



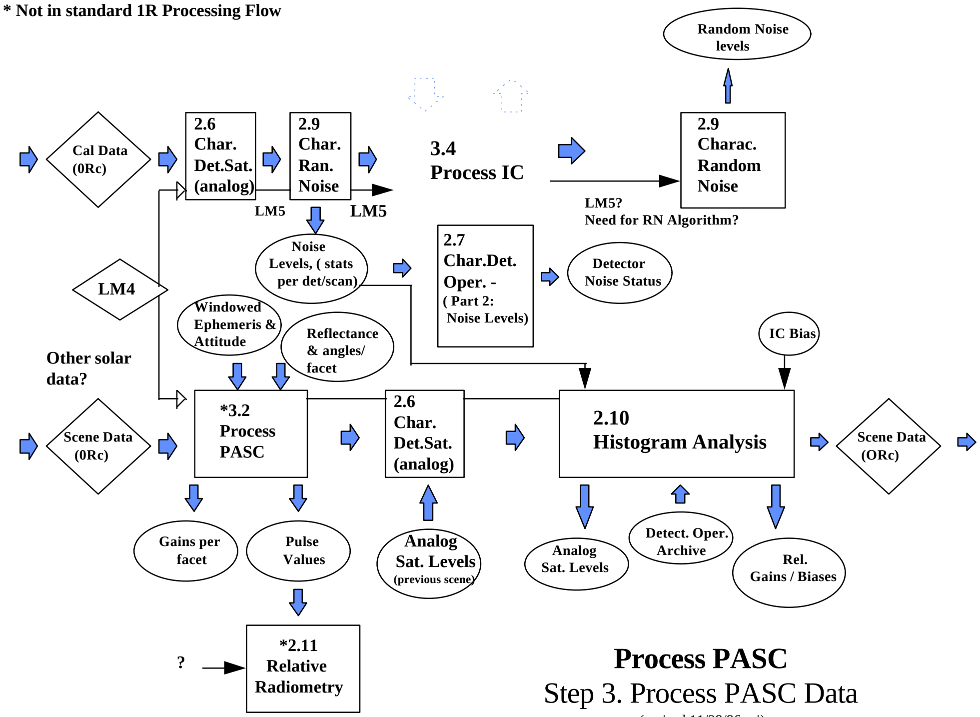
* Not in Standard Level 1R Flow
2.2.p algorithm applies to PASC only
^ saved by source (night, PASC, or FASC

Process PASC

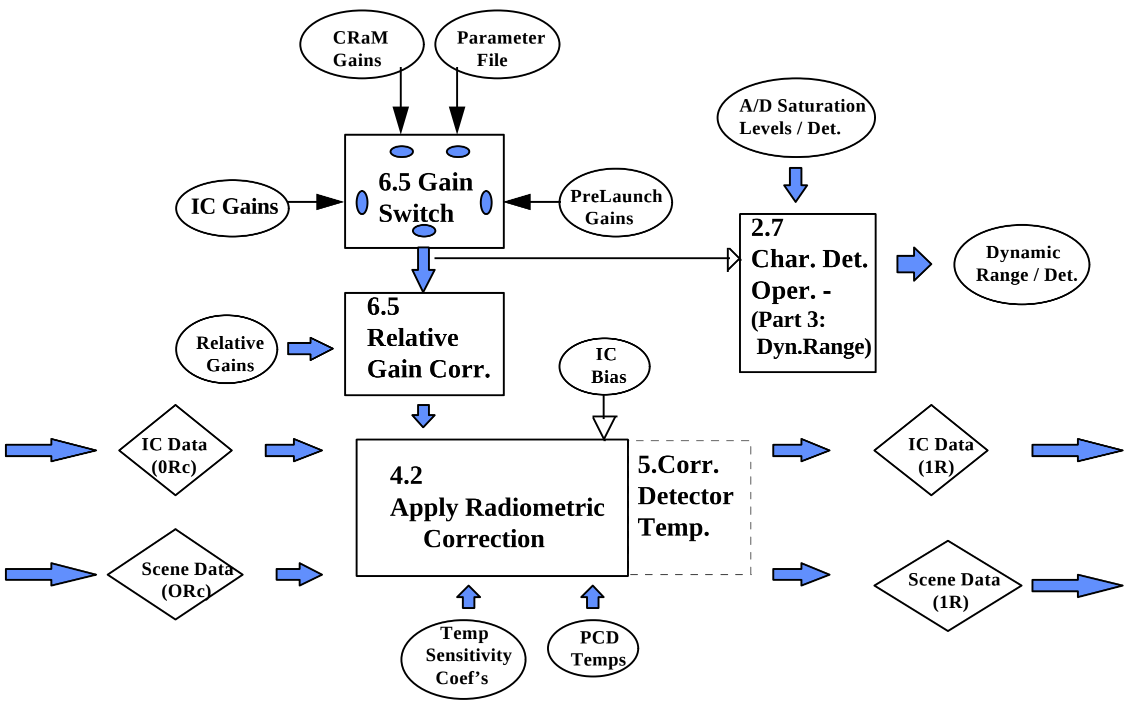
Step 2. Memory Effect Characterization

(revised 11/29/96 ssj)

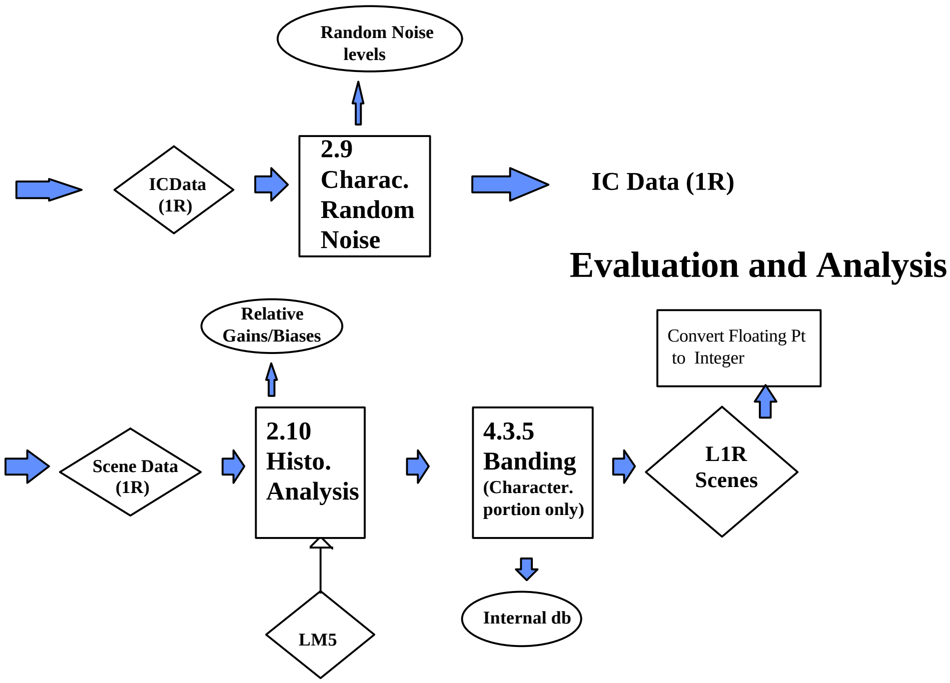
* Not in standard 1R Processing Flow



Process PASC
Step 3. Process PASC Data
(revised 11/29/96 ssj)



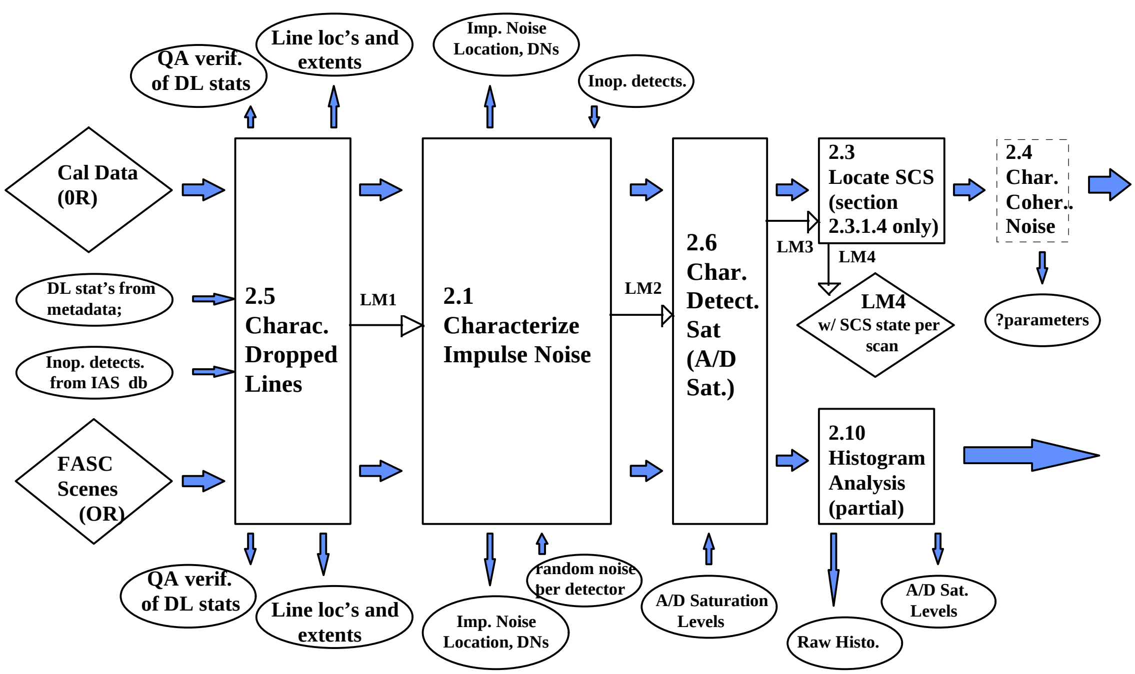
Process PASC
Step 4. 1R Correction
(revised 11/29/96 ssj)



Process PASC

Step 5. 1R Radiometric Characterization/Correction

(revised11/29/96 ssj)

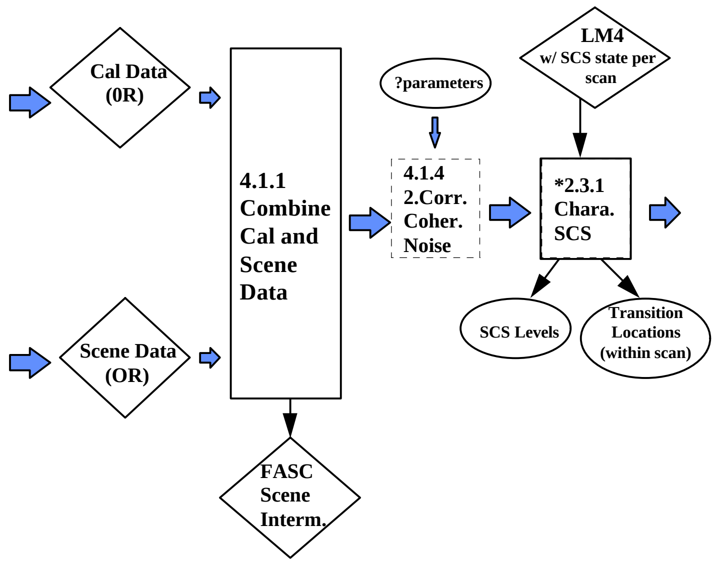


Process FASC

Step 1. 0R Radiometric Characterization

(update 11/29/96 ssj)

*** Not in Standard 1R processing**

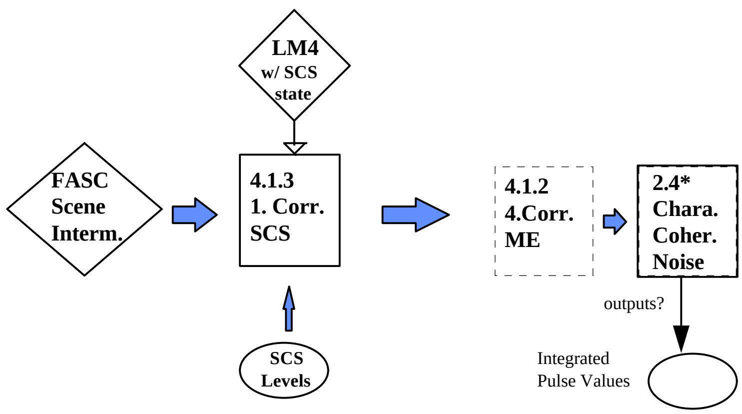


Process FASC

Step 2. Scan Correlated Shift Characterization

(revised 11/29/96 ssj)

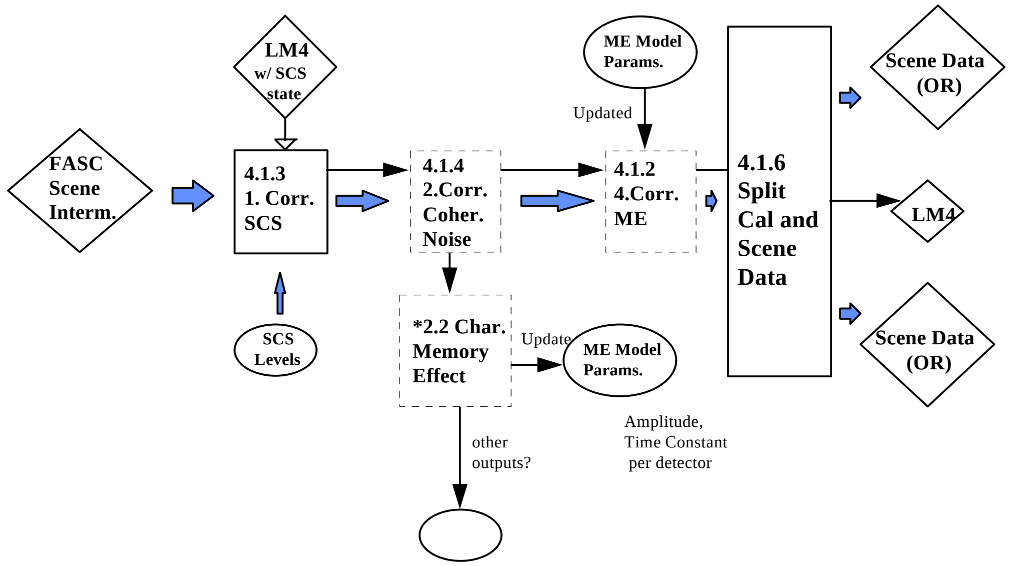
*** Not in Standard Level 1R Flow**



Process FASC

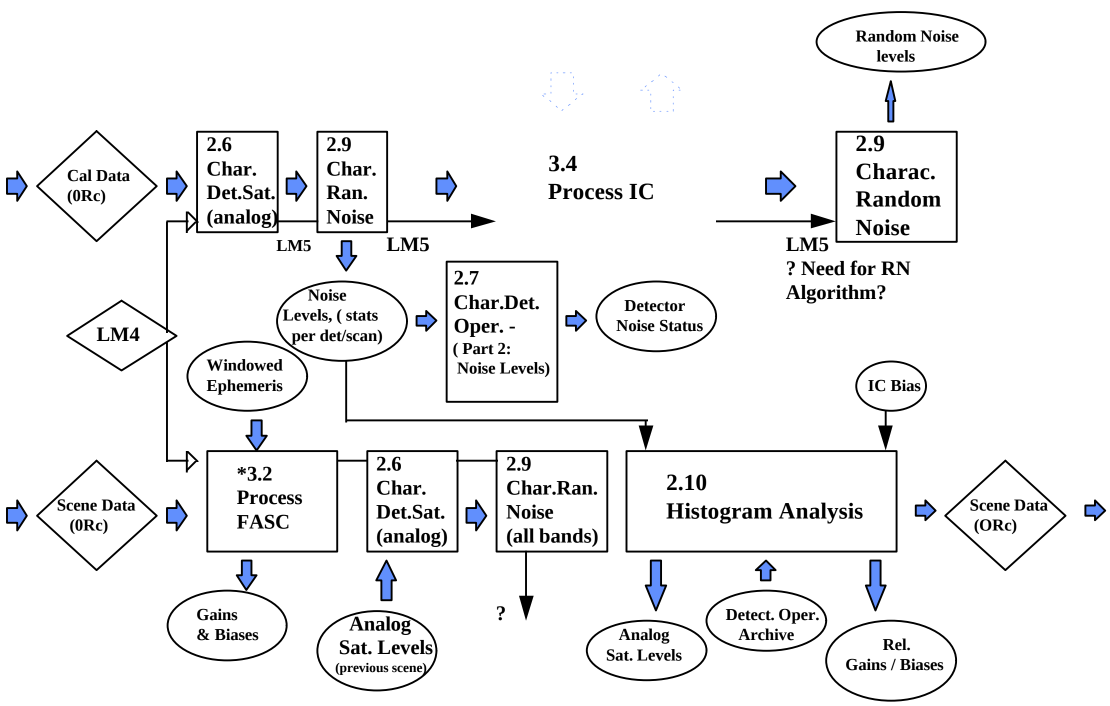
Step 3. Coherent Noise Characterization

(revised 11/29/96 ssj)



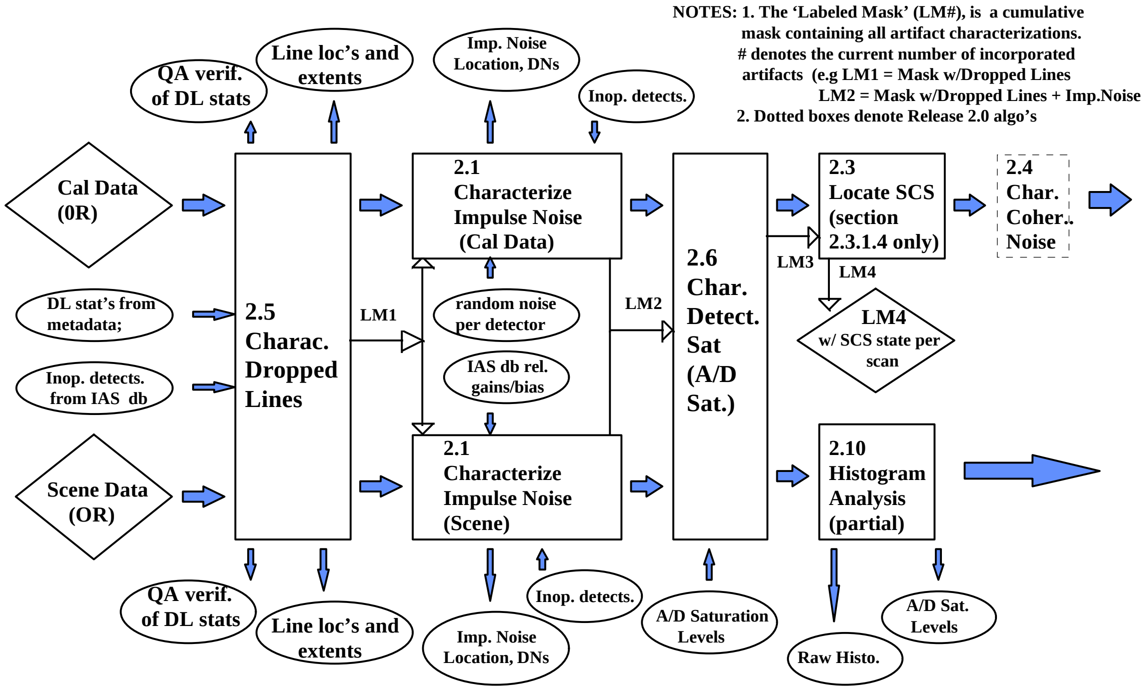
* Not in Standard Level 1R Flow
ME char. unique by source

Process FASC
Step 4. Memory Effect Characterization
(revised 11/29/96 ssj)



* Not in standard 1R Processing Flow

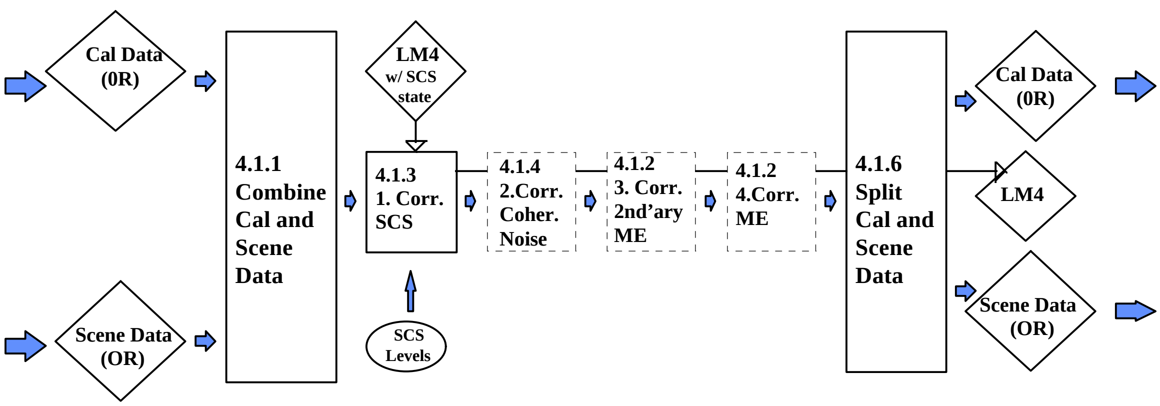
Process FASC
Step 5. Process FASC Data
(revised 11/29/96 ssj)



Processing MTF Scene

Step 1. 0R Radiometric Characterization

(update 9/11)



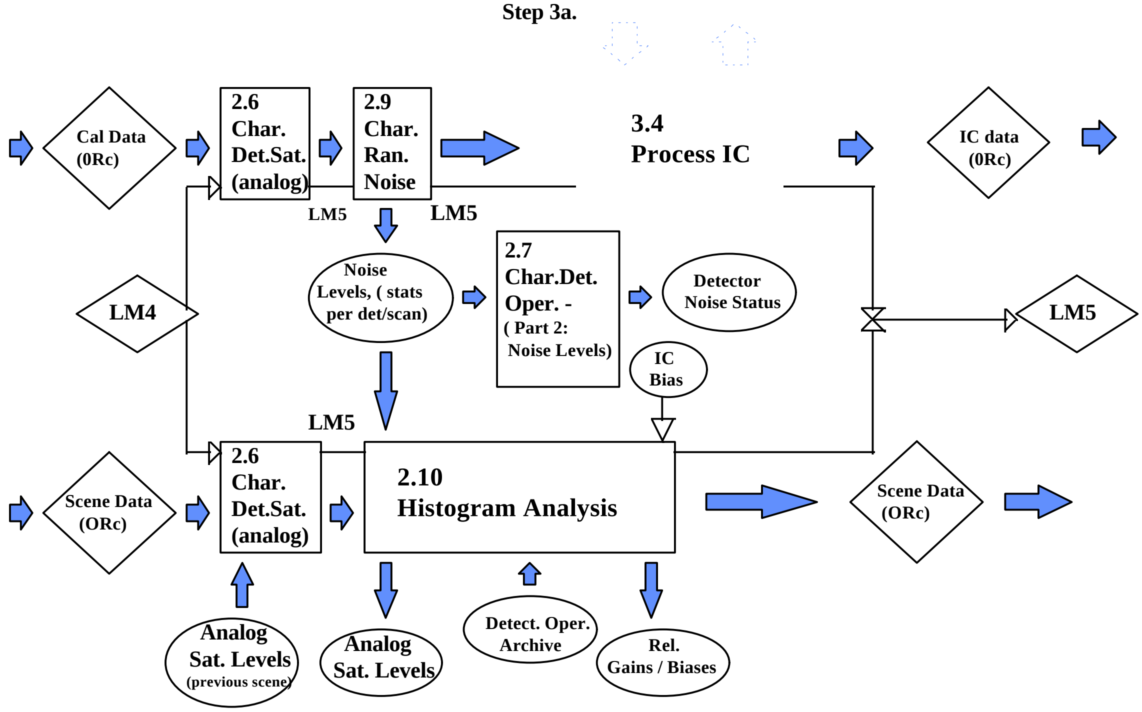
Note: Dotted boxes denote Release 2.0 algorithms

Processing MTF Scene

Step 2. Pre-1R Correction

(revised 9/9)

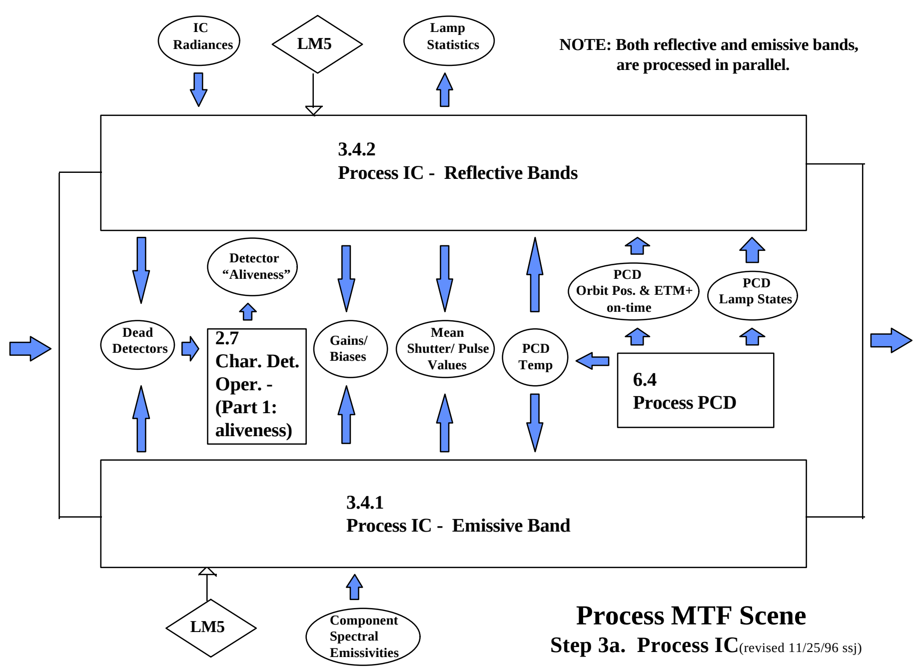
Notes: 1. Dotted boxes denote Release 2.0 algo's
2. For algorithm "3.4 Process IC", see detailed flow in Step 3a.



Processing MTF Scene

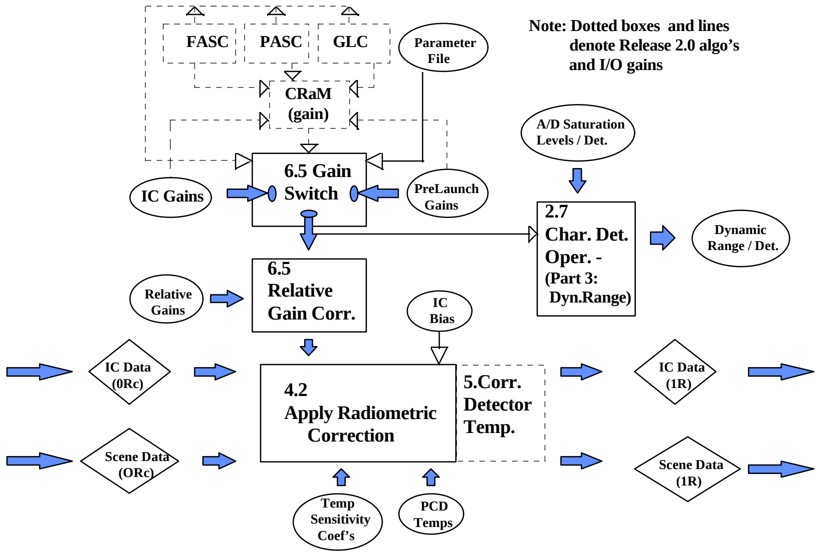
Step 3. 0Rc Radiometric Characterization/Calibration

(revised 11/25/96 ssj)

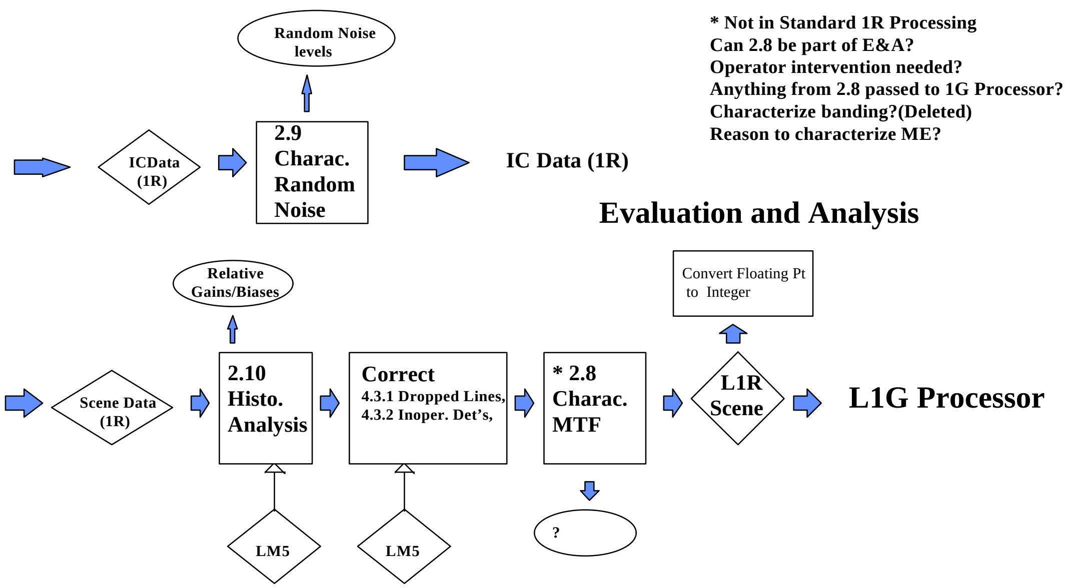


Process MTF Scene

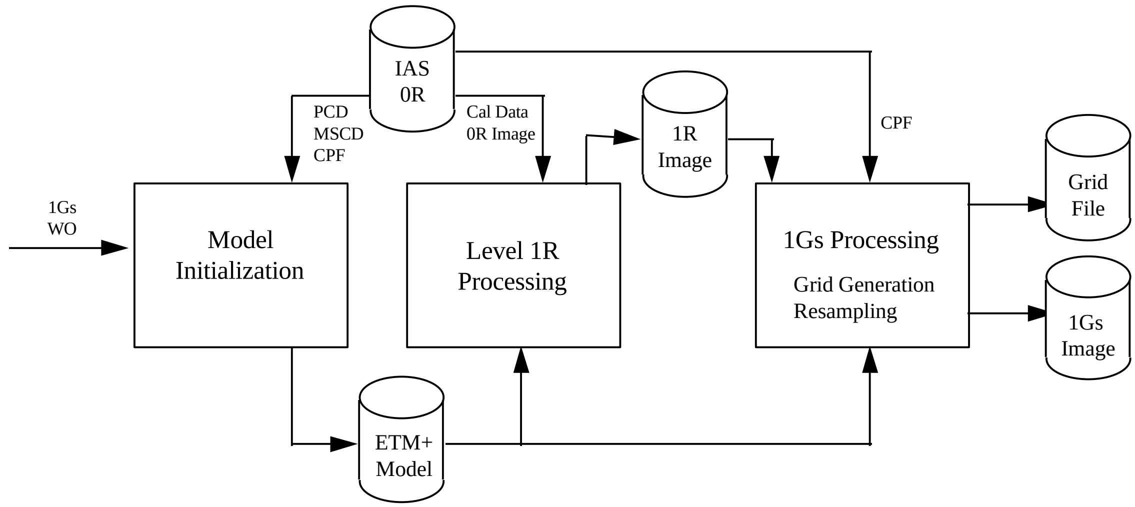
Step 3a. Process IC(revised 11/25/96 ssj)



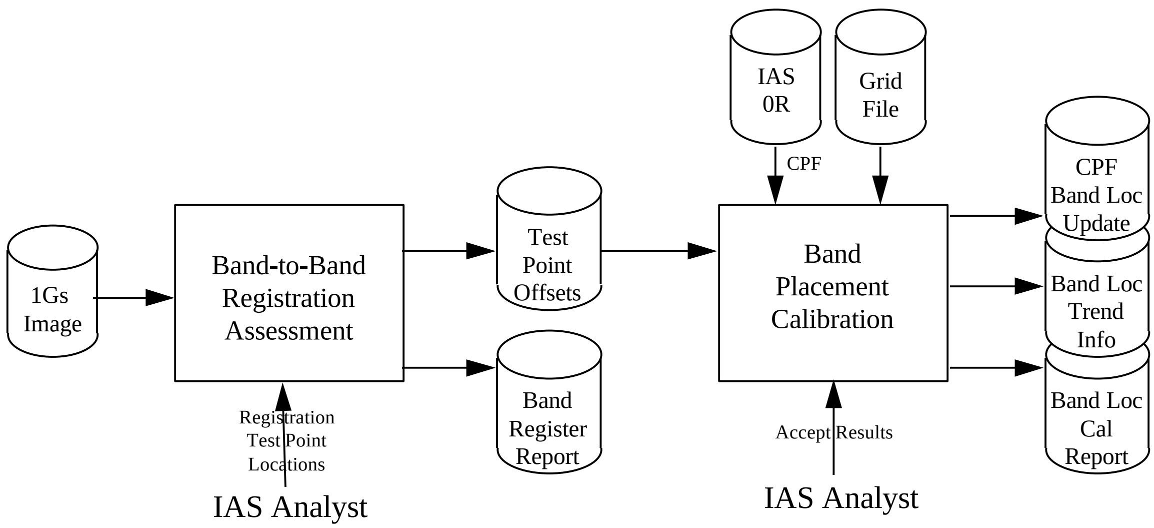
Processing MTF Scene
Step 4. 1R Correction
(revised 9/11)



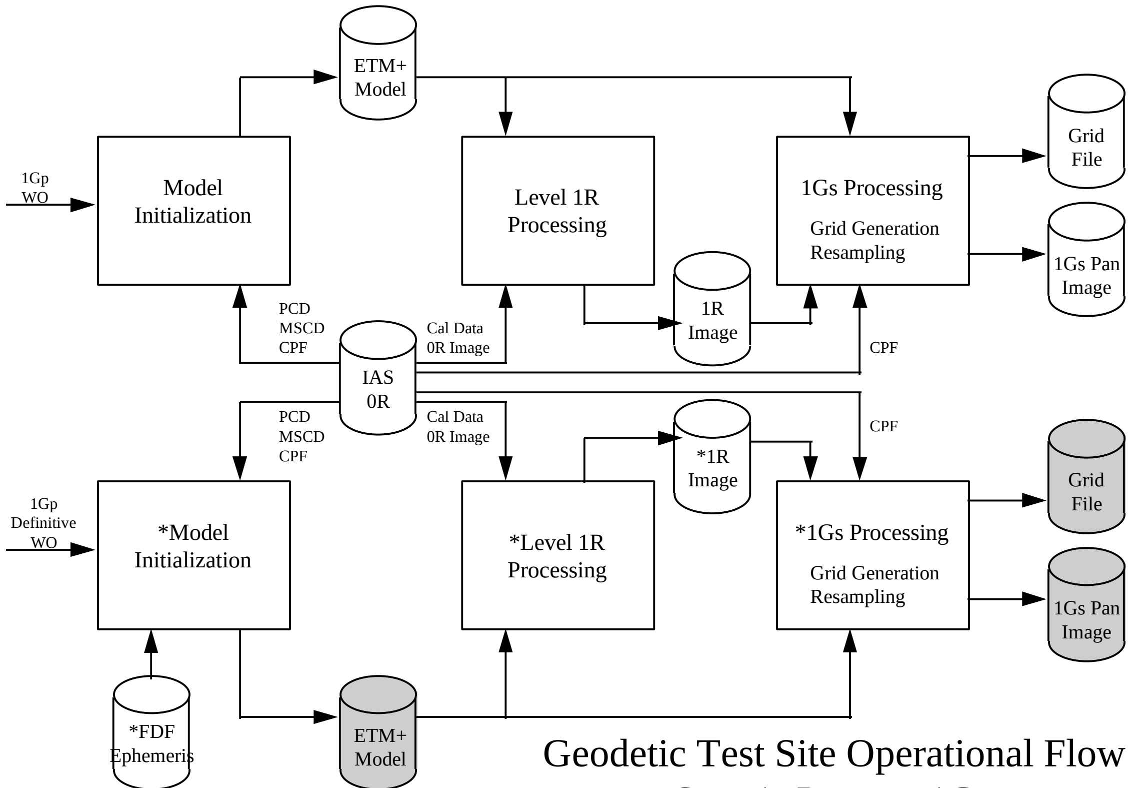
Processing MTF Scene
Step 5.0 MTF Characterization
(revised11/25/96)



Focal Plane Calibration Operational Flow
Step 1- Process 1Gs

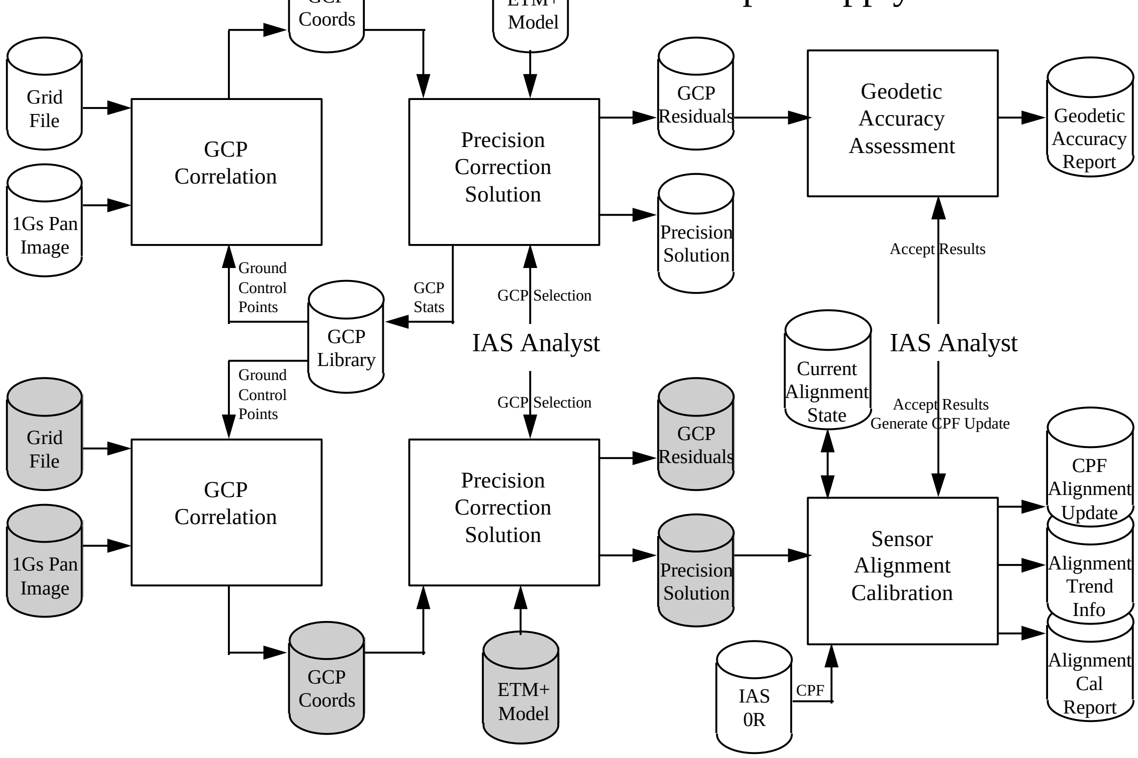


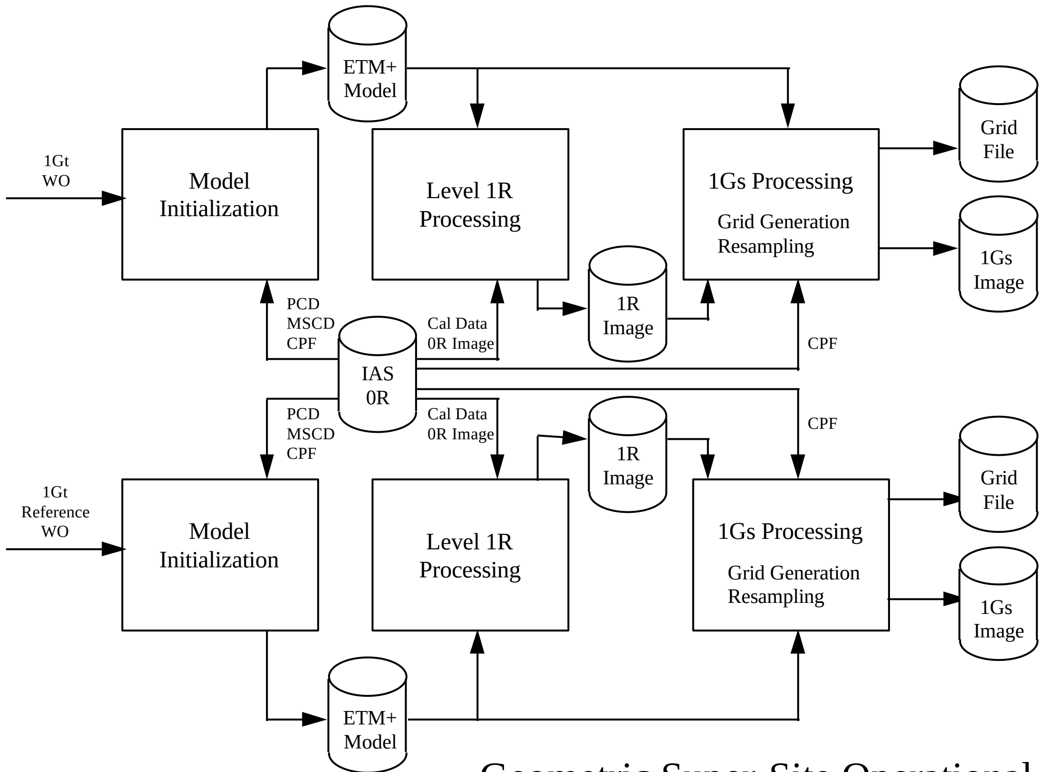
Focal Plane Calibration Operational Flow
Step 2- Assess and Calibrate



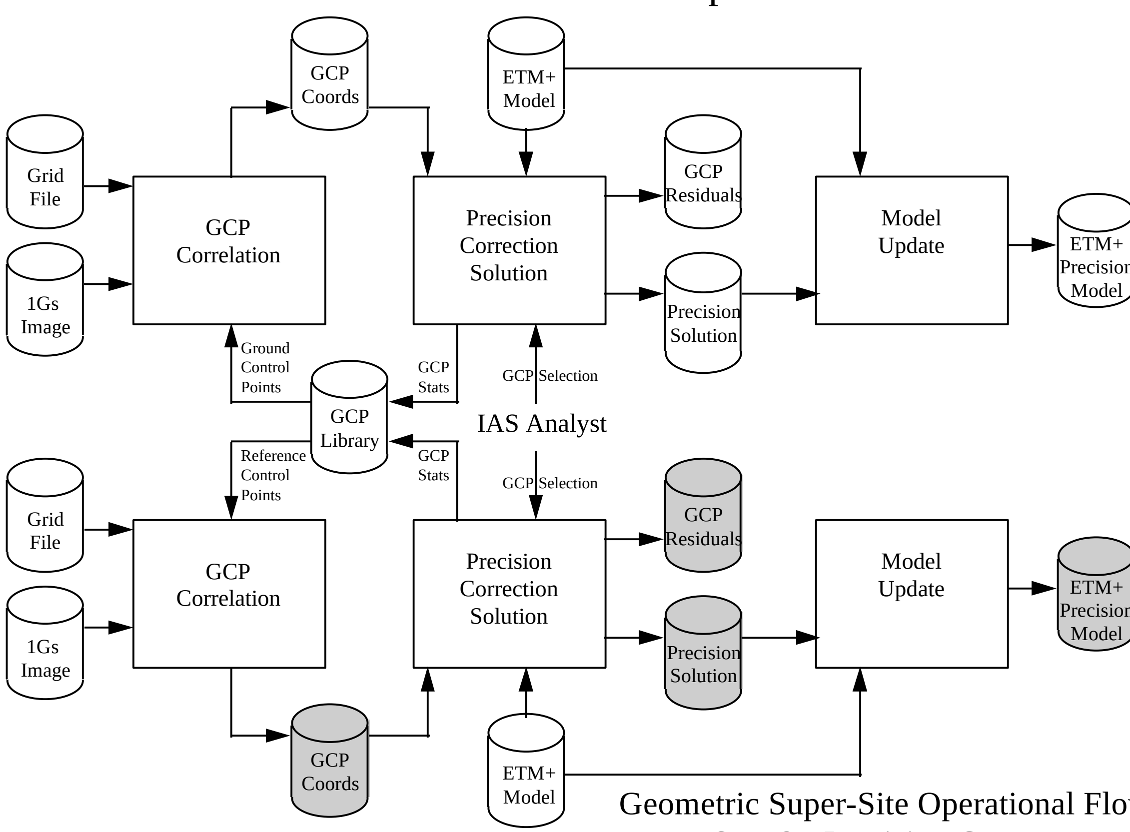
Geodetic Test Site Operational Flow
Step 1- Process 1Gs

Geodetic Test Site Operational Flow
Step 2- Apply GCPs





Geometric Super-Site Operational Flow
Step 1- Process 1Gs



Geometric Super-Site Operational Flow
Step 2- Precision Correct

Glossary

Ancillary data: Spacecraft attitude and ephemeris, radiometric correction coefficients, geometric processing parameters, and image quality statistics.

Archive: Off-line storage of data, software, and documentation.

Band: A range of spectral frequencies.

Bright Target Recovery: Also known as memory effect.

Browse Image File: A reduced data volume file of the Level 0R data which can be viewed to determine general ground area coverage and spatial relationships between ground area coverage and cloud coverage. This file contains reduced resolution scenes of the full resolution scene data contained in the Level 0R instrument data files of a sub-interval.

Calibration activities: Recalculating of the radiometric correction coefficients or geometric processing parameters.

Calibration Parameter File: The primary product of IAS that captures parameters needed to calibrate the raw instrument data.

Calibration Result: The result of performing a calibration operation. Gains, biases, offsets.

Characterization Result: The result of performing a characterization operation. Identifies an image artifact location and magnitude.

Dead detectors: A detector which provides no change in output DN for changes in input radiance.

Degraded detectors: Also known as inoperable detectors (see definition).

Detector: Instrument sensor that detects radiation from the Earth in certain spectral frequency bands.

Detector Operability: Determination of whether a detector "dead" (i.e., one which provides no change in output DN for changes in input radiance or has fallen out of acceptable performance limits.

Dropped Lines: Pixels or telemetry minor frames that were transmitted with unrecoverable communications errors or that were completely dropped from the telemetry stream.

Equivalent at-aperture radiance: Estimated radiance from other than full-aperture radiance.

Entrance aperture radiance: Actual full-aperture radiance.

Full Aperture Solar Calibrator: A deployable panel painted with a highly reflective diffuse paint. This panel is deployed as the satellite passes over the terminator in the vicinity of the North pole, and reflects solar radiation into the full ETM+ aperture.

Geodetic accuracy: The accuracy relative to the geodetic reference surface, the Earth ellipsoid.

Geometric accuracy: The measure of internal distortion of an image.

Geometric artifacts: Assessment of geometric artifacts (or assessment of geometric accuracy) includes visual assessment of discontinuities of linear features, scale distortion, panoramic distortion, and any other distortions.

Geometric processing parameters: Orbit parameters, instrument and alignment parameters, focal plane band locations, scan mirror profile coefficients (along scan and across scan), odd detector sample shifts, alignment matrixes, Angular Displacement Sensor (ADS) calibration parameters, gyro calibration parameters, along scan focal plane detector offsets, temperature calibration coefficients, inoperable modes, resampling coefficients, MTF coefficients, and MTF compensation.

Ground look calibration: The process of radiometrically calibrating the payload, on-orbit, by comparing payload readings to estimated radiances reaching the payload from ground scenes using onsite ground and atmospheric measurements.

IAS Subinterval: 3 WRS scenes of data concatenated together.

Impulse Noise: Within a digital signal, impulse noise manifests itself in the occasional sample as a departure from the signal trend far in excess of that expected from random noise.

In-orbit checkout (IOC): The 45-day period specified after launch during which spacecraft and sensor systems are activated, checked out, outgassed, and initially calibrated.

Initial operational capability: Milestone after satellite initialization and checkout wherein operations are transferred from the developers (NASA) to the system operators (NOAA).

Inoperable detectors: Detectors meeting the following criteria shall be declared inoperable:

The quantized digital number (DN) is below 50 percent of the full-scale DN value when a detector is exposed to the ETM+ minimum saturation levels.

The quantized DN reaches full scale while the input radiance is at or below 0.70 times the ETM+ minimum saturation levels.

The SNR performance degrades to 50 percent or below the specified ETM+ minimum SNR values.

Internal Calibration File: One file is created for each sub-interval. This file contains all of the calibration data received on a major frame basis for a given sub-interval. The data are grouped by detectors, i.e., for a given major frame, detector 1 data is followed by detector 2 data etc. Reverse scans are reversed. The spacecraft time of the major frame corresponding to this data is appended, as well as the status data.

Level 0R: The stage in the processing before radiometric or geometric correction of an image and after the pixels have been placed in detector spatial order.

Level 0R Image File: Each file contains the image data from a single band in a single subinterval. The data is grouped by detectors, i.e., for a given major frame, detector 1 data is followed by detector 2 data etc. Reverse scan samples are changed to forward order. This data is nominally aligned using fixed and predetermined integer values that provide alignment for band offset, even/odd detectors, and forward and reverse scans. Quality indicators are appended for each major frame.

Level 0R product: Products distributed by the EDC DAAC, to include one file per band of Level 0R image data, metadata, internal calibration (IC) data, calibration parameter file, payload correction data (PCD), and mirror scan correction data (MSCD).

Level 0Rc Image: Level 0R image processed through the Pre-1R Correction processing step (includes correction for Scan Correlated Shift and Memory Effect).

Level 1G: The stage in the processing in which the image data are geometrically corrected.

Level 1G Image: Image data that have been both radiometrically and geometrically corrected.

Level 1R: The stage in the processing in which the image data are radiometrically corrected.

Level 1R Image: Image data that have been radiometrically corrected.

Mean Time To Repair (MTTR): The period of time consisting of the mean time required from failure detection, through troubleshooting, fault localization, removal and replacement of failed LRUs, adjustment/calibration of repaired equipment and verification that the specified performance requirements are met.

Memory Effect: a noise pattern commonly known as banding. It can be observed as alternating lighter and darker horizontal stripes that are 16 pixels wide in data that has not been geometrically corrected.

Metadata: One metadata file is created for each sub-interval. The metadata contains information on the Level 0R data provided in the sub-interval, the names of the Level 0R instrument data, calibration data, payload correction data, mirror scan correction data and browse image files associated with the sub-interval. Metadata also contains quality and accounting information on the return link wideband data used in generating the level 0R file(s). In addition, metadata includes quality and accounting information on received and processed PCD, and cloud cover assessment for the WRS scene contained in the sub-interval. The metadata is used by the LP DAAC users to determine the sub-interval and/or WRS scene level quality of the Level 0R data stored in the LP DAAC archive before ordering it on a cost basis.

Mirror Scan Correction Data: One file is created for each sub-interval. This file contains the Scan Line Data extracted from the two minor frames following the End of Line Code in each major frame of the sub-interval . The Scan Line Data includes the first half scan error (FHS ERR), the second half scan error (SHS ERR), and the Scan direction (SCN DIR) information. The spacecraft time of the major frame corresponding to this data is appended.

Modulation Transfer Function: In imaging systems, the impulse response is called the point spread function (PSF) and the transfer function is called the optical transfer function (OTF). The magnitude of the OTF is called the modulation transfer function (MTF).

Partial Aperture Solar Calibrator: A small passive device that is attached to the ETM+ sun shade and permanently obscures a small portion (~0.5%) of the aperture. It consists of four essentially identical sets of optical elements each in a slightly different orientation.

Payload Correction Data (PCD): The PCD contain all data required by ground stations to geometrically correct ETM+ sensor data and redundantly provide the ETM+ imaging configuration. The PCD are embedded in every wideband data virtual channel data unit (VCDU) at a rate of 4 bytes of PCD per VCDU One file is created for each subinterval..

Radiometric processing parameters: Includes the radiometry parameters in the calibration parameter file (prelaunch gains, initial postlaunch gains, most current gains, detector status table, offset window locations, nominal biases, and scale factors) plus

IAS-maintained calibration parameters from individual calibration sources and the combined radiometric model (CRAM).

Radiometric image artifacts: Striping, banding, scan correlated shift, bright target recovery response (aka memory effect), coherent noise, impulse noise, detector saturation, and detector inoperability.

Scan-Correlated Shift: A sudden change in bias that occur in all detectors simultaneously. The bias level switches between two states.

Sub-Interval: A segment of raw wideband data interval received during a Landsat 7 contact period. Sub-intervals are caused by breaks in the wideband data stream due to communication dropouts and/or the inability of the spacecraft to transmit a complete observation (interval) within a single Landsat 7 contact period. The largest possible sub-interval can be as long as a full imaging interval. The smallest possible sub-interval can be as small as one full ETM+ scene with a time duration of approximately 24 seconds.

Test sites: Geometric test sites.

Work Order: Mechanism used to capture user processing requirements and to control the processing.

Acronym List

ANSI	American National Standards Institute
COTS	Commercial Off-The-Shelf
DAAC	Distributed Active Archive Center
DBMS	Data Base Management System
DMS	Data Management System
E&A	Evaluation and Analysis
EDC	EROS Data Center
EROS	Earth Resources Observation Systems
ETM+	Enhanced Thematic Mapper +
ENVI	Environment for Visualizing Imagery
FASC	Full Aperture Solar Calibrator
GLC	Ground Look Calibration
GPS	Geometry Processing Subsystem
GUI	Graphical User Interface
HDF	Hierarchical Data Format
HWC	Hardware Component
HWCI	Hardware Configuration Item
IAS	Image Assessment System
IC	Internal Calibrator
ICD	Interface Control Document
IDL	Interactive Data Language
LPS	Landsat Processing System
MMAS	Martin-Marietta Astro Space

MMO	Mission Management Office
MOC	Mission Operations Center
NCSA	National Center for Supercomputer Applications
NDI	Non-Development Item
PASC	Partial Aperture Solar Calibrator
PCS	Process Control Subsystem
PVCS	? Version Control System
RPS	Radiometry Processing Subsystem
SBRS	Santa Barbara Research Systems
SGI	Silicon Graphics, Inc.
SWCI	Software Configuration Item
UI	User Interface

3.0 SYSTEM DESIGN SPECIFICATION

This section provides a detailed description of the three IAS geometric subsystems. The allocated requirements, interfaces, functional descriptions, major data items, and software are described for each subsystem.

Requirements Allocation

The following table maps the requirements to each of the geometric subsystems:

Level 1Geometry	Geometric Characterization	Geometric Calibration
3.2.2.3.1	3.2.2.3.6	3.2.2.2.1
3.2.2.3.3	3.2.2.4.8	3.2.2.2.2
3.2.2.3.4	3.2.2.4.9	3.2.2.2.3
3.2.2.3.5	3.2.2.4.10	3.2.2.2.4
3.2.2.3.7	3.2.2.4.11	3.2.2.6.13
3.2.2.3.8	3.2.2.6.13	3.2.3.10
3.2.2.3.9	3.2.3.7	3.2.3.12
3.2.2.3.10	3.2.3.8	3.2.4.8
3.2.2.3.11	3.2.3.9	
3.2.2.3.12	3.2.3.11	
3.2.2.3.15	3.2.4.8	
3.2.2.4.12		
3.2.2.6.13		
3.2.3.3		
3.2.3.4		
3.2.3.5		
3.2.3.6		

Table 3-1: Geometric Subsystem Requirements Mappings

Interfaces
Figure 3-A illustrates the IAS geometric processing context diagram to the other subsystems within IAS. See Appendix A for the geometric processing data dictionary.

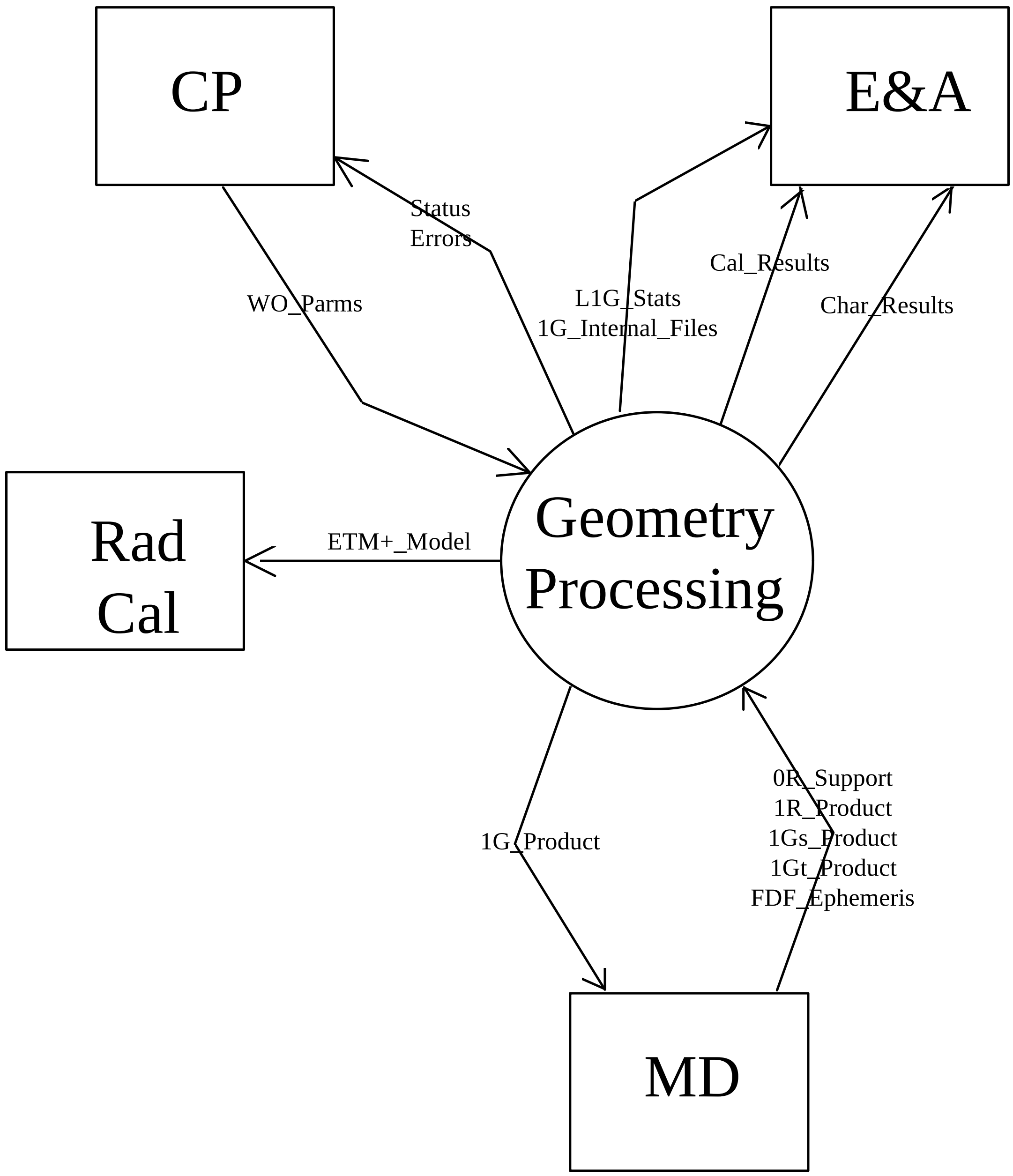


Figure 3-A: Geometric Context Diagram

External Interfaces

Table 3-2 defines the external interfaces to the geometric subsystem.

Data Flow	Data Store Type	From	To	Interface Type	Comments
Work Order Parms	Oracle DB / HDF File	CP	1G, Geo Char, Geo Cal	HDF File	HDF file generated from DB
Alignment Matrix	Oracle DB	Geo Cal	E&A	C API	CPF Field
Attitude Sequence	Oracle DB	Geo Cal	E&A	C API	Trending Info
Attitude Statistics	Oracle DB	1G	E&A	C API	Trending Info
B2B Statistics	Oracle DB	Geo Char	E&A	C API	Trending Info
Band Center Locations	Oracle DB	Geo Cal	E&A	C API	CPF Field
Errors	Oracle DB	1G, Geo Char, Geo Cal	CP	C API	Error Message
Geodetic Statistics	Oracle DB	Geo Char	E&A	C API	Trending Info
I2I Statistics	Oracle DB	Geo Char	E&A	C API	Trending Info
Innovation Sequence	Oracle DB	Geo Cal	E&A	C API	Trending Info
Mirror Profile Coefficients	Oracle DB	Geo Cal	E&A	C API	CPF Field
Mirror Scan Statistics	Oracle DB	Geo Cal	E&A	C API	Trending Info
Orbit Sequence	Oracle DB	Geo Cal	E&A	C API	Trending Info
Polynomial Coefficients	Oracle DB	Geo Char	E&A	C API	Trending Info
Scan Gap Statistics	Oracle DB	1G	E&A	C API	Trending Info
Status	Oracle DB	1G, Geo Char, Geo Cal	CP	C API	Processing Status
1Gp Image	HDF File	1G	MD	HDF File	Image File
1Gs Image	HDF File	1G	MD	HDF File	Assume 1G images are managed by MD
1Gs Image	HDF File	MD	Geo Char	HDF File	Image File
1Gt Image	HDF File	1G	MD	HDF File	Image File
1Gt Image	HDF File	MD	Geo Char, Geo Cal	HDF File	Image File
1R Image	HDF File	MD	1G	HDF File	Image File
CPF	HDF File	MD	1G, Geo Cal	HDF File	0R Product DFCB
DDR	HDF File	1G	MD, E&A	HDF File	To E&A for Viewing
DDR	HDF File	MD	1G, Geo Char, Geo Cal	HDF File	DDRs accompany all image files
Geometric Grid	HDF File	1G	E&A	HDF File	To E&A for Viewing
Metadata	HDF File	MD	1G	HDF File	0R Product DFCB
MSCD	HDF File	MD	1G	HDF File	0R Product DFCB

PCD	HDF File	MD	1G	HDF File	0R Product DFCB
Alignment Calibration Report	ASCII File	Geo Cal	E&A	ASCII File	Text file containing formatted presentation of state file, orbit sequence, attitude sequence, innovation sequence and alignment matrix (if generated).
B2B Calibration Report	ASCII File	Geo Cal	E&A	ASCII File	Text file containing Band Center Locations and B2B residuals (post-B2B calibration).
B2B Residuals	ASCII File	Geo Char	E&A	ASCII File	To E&A for Viewing
Band Registration Report	ASCII File	Geo Char	E&A	ASCII File	Text file containing B2B Stats and B2B residuals.
ETM+ Model	ASCII File	1G	E&A	ASCII File	To E&A for Viewing
ETM+ Model	ASCII File	1G	Rad Cal	C API	Calls to map input pixel/line to ground
FDF Ephemeris	ASCII File	MD	1G	ASCII File	MOC/IAS ICD
Geodetic Accuracy Report	ASCII File	Geo Char	E&A	ASCII File	Text file containing Geodetic Stats and Precision Correction Residuals
Geometric Accuracy Report	ASCII File	Geo Char	E&A	ASCII File	Text file containing Visual Stats, GCP Residuals, and Poly Residuals
Image Registration Report	ASCII File	Geo Char	E&A	ASCII File	Text file containing I2I Stats and I2I residuals.
Metadata Report	ASCII File	1G	E&A	ASCII File	To E&A for Viewing
Mirror Calibration Report	ASCII File	Geo Cal	E&A	ASCII File	Text file containing formatted presentation of Mirror Scan Stats and Mirror Profile Coefficients
State File	ASCII File	Geo Cal	E&A	ASCII File	To E&A for Viewing

Table 3-2: Geometry Subsystem External Interfaces

Data Flow
Figure 3-B represents the data flow diagram for the three geometric subsystems of the IAS. See Appendix A for the data dictionary definitions.

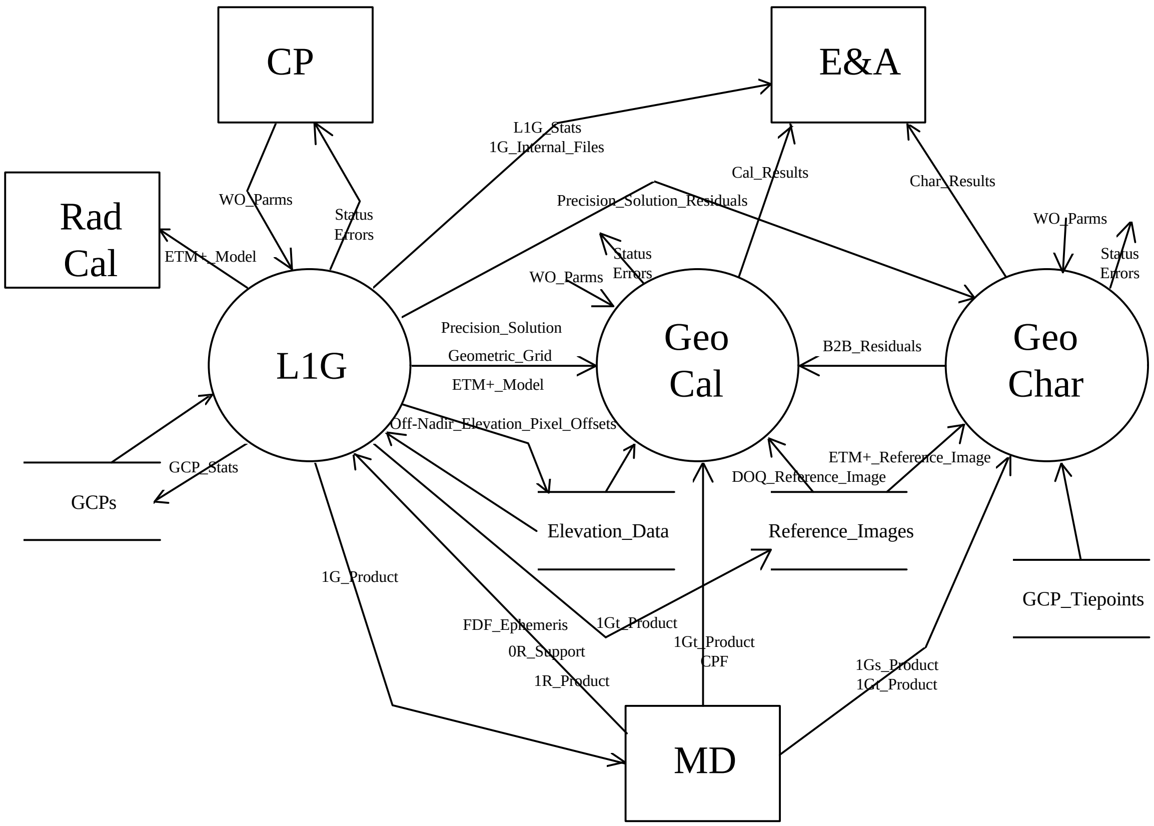


Figure 3-B: Geometric Processing Data Flow Diagram

Internal Interfaces
Table 3-3 defines the internal interfaces within the geometric subsystem.

Data Flow	Data Store Type	From	To	Interface Type	Comments
DDR	HDF File	1G	Geo Char	HDF File	Accompanies 1Gt ETM+ Reference Image
DDR	HDF File	Geom Permanent Data	1G, Geo Cal	HDF File	Permanent supporting data set (created by test tools) accompanying Elevation Image and DOQ Reference Image
DOQ Reference Image	HDF	Geom	Geo Cal	HDF File	Permanent supporting data

	File	Permanent Data			set created by test tools
Elevation Image	HDF File	Geom Permanent Data	1G, Geo Cal	HDF File	Permanent supporting data set created by test tools
ETM+ Reference Image	HDF File	1G	Geo Char	HDF File	1Gt kept as permanent data set
GCP Imagery	HDF File	Geom Permanent Data	1G	HDF File	Permanent supporting data set created by test tools
GCP Statistics	HDF File	1G	Geom Permanent Data	HDF File	Updates fields in permanent HDF GCP tiepoint file
GCP Tiepoints	HDF File	Geom Permanent Data	1G, Geo Char	HDF File	Permanent supporting data set created by test tools
Geometric Grid	HDF File	1G	Geo Cal	HDF File	For Scan Mirror & B2B
B2B Residuals	ASCII File	Geo Char	Geo Cal	ASCII File	Pixel, line coordinates and deltas for all test points and all band pairs
ETM+ Model	ASCII File	1G	Geo Cal	ASCII File	For Scan Mirror Cal
Off Nadir Elev Pixel Offsets	ASCII File	1G	Geo Cal	ASCII File	Resampler output
Precision Solution	ASCII File	1G	Geo Cal	ASCII File	For Alignment Cal
Precision Solution Residuals	ASCII File	1G	Geo Char	ASCII File	GCP locations, pre- and post-fit residuals, and outlier flags

Table 3-3: Geometry Subsystem Internal Interfaces

3.1 LEVEL 1 GEOMETRY (L1G) SUBSYSTEM

The L1G subsystem processes raw (OR) or radiometrically corrected (1R) imagery to geometrically corrected (1G) imagery. A 1G image can be processed to three levels; systematic (1Gs), precision corrected (1Gp), and precision/terrain corrected (1Gt).

The ETM+ satellite model, generated from the input PCD and MSCD information and optionally, definitive ephemeris (geometric calibrations), is used to setup the relationship between input space and the user defined output projection space. This relationship is defined in a grid structure that is used to resample the input image into the output space. Resampling supports nearest neighbor (NN), cubic convolution (CC), and modulation transfer function (MTF) weighted cubic convolution options.

To generate a 1Gp image the ETM+ satellite model is updated using ground control points in the precision correction process. The new ETM+ satellite model is used to recreate a precision grid structure for the resampling process. Elevation information can also be used during the resampling to correct for terrain offsets to create a 1Gt image.

Requirements Allocation

The following list maps the requirements to the L1G subsystem.

3.2.2.3.1 The IAS shall be capable of processing payload correction data (PCD) data to correct spacecraft time, generate a sensor pointing model (attitude and jitter), and calculate spacecraft position and velocity (ephemeris).

3.2.2.3.3 The IAS shall be capable of creating systematically corrected ETM+ Level 1G imagery from level 0R products.

3.2.2.3.4 The IAS shall be capable of creating precision corrected ETM+ Level 1G imagery from level 0R products and ground control points (GCPs).

3.2.2.3.5 The IAS shall be capable of creating terrain corrected ETM+ Level 1G imagery from level 0R products, GCPs, and elevation data.

3.2.2.3.7 The IAS shall be capable of incorporating IAS-generated calibration coefficient updates to generate Level 1 data.

3.2.2.3.8 The IAS shall support nearest neighbor, cubic convolution, and modulation transfer function (MTF) compensation resampling.

3.2.2.3.9 The IAS shall have the capability to produce a 1G product with a grid cell size that is variable from 15 to 60 meters, in increments of 1 millimeter (mm).

3.2.2.3.10 The IAS shall have the capability to map project 1G using the Space Oblique Mercator, Universal Transverse Mercator, Lambert Conformal Conic, Transverse Mercator, Oblique Mercator, and Polyconic coordinate reference systems.

3.2.2.3.11 The IAS shall have the capability to create a 1G image oriented to nominal path or north-up.

3.2.2.3.12 The IAS shall be capable of processing mirror scan correction data (MSCD) to generate scan mirror and scan line corrector mirror models..

3.2.2.3.15 The IAS shall be capable of processing to Level 1R and 1G both ascending and descending pass ETM+ Level 0R data.

3.2.2.4.12 The IAS shall be able to evaluate the quality of level 0R products. Quality checks will include but not be limited to those listed in Table 3.2.2.4-1.

Table 3.2.2.4-1 L0R Product Quality Checks (geometry only)

Imagery	**Payload Correction Data**
Visual Check	Validated in 1G model
Process to 1R/1G	
Metadata	**Mirror Scan Correction Data**
Scene coordinates	Validated in 1G model
WRS scene parameters correctness (Sun angles, scene center lat/long, asc/desc flag, etc).	

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.3.3 The IAS shall contribute no greater than .7% uncertainty to absolute radiometric accuracy during the generation of level 1R and 1G data.

3.2.3.4 The IAS shall be able to create systematic imagery to a geodetic accuracy of 250 meters, 1 sigma, providing all inputs are within specification. Performance applies to along-track and cross-track directions, and is referenced to a nadir-viewing geometry.

3.2.3.5 The IAS shall contribute circular errors no greater than 1.8 m, 1 sigma, in the production of systematically corrected ETM+ Level 1G imagery. This error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.

3.2.3.6 The IAS shall provide the capability to register pixels from a band to the corresponding pixels of the other bands in a common scene to an accuracy of 0.28 sensor GSD, 0.9p, in along-track and cross-track directions providing all inputs are within specification. The accuracy is relative to the largest sensor GSD of the registered bands.

Algorithm Allocation

The following algorithms are allocated to the L1G subsystem:

- Attitude Processing
- Create Model
- Call Model
- Geometric Griding
- Detector Delay Resampling Weights
- Terrain Correction
- Resampling
- Precision Correction

Interfaces
Figure 3-C illustrates the L1G subsystem context and external interfaces. Appendix A contains the data dictionary for the level 1G context diagram.

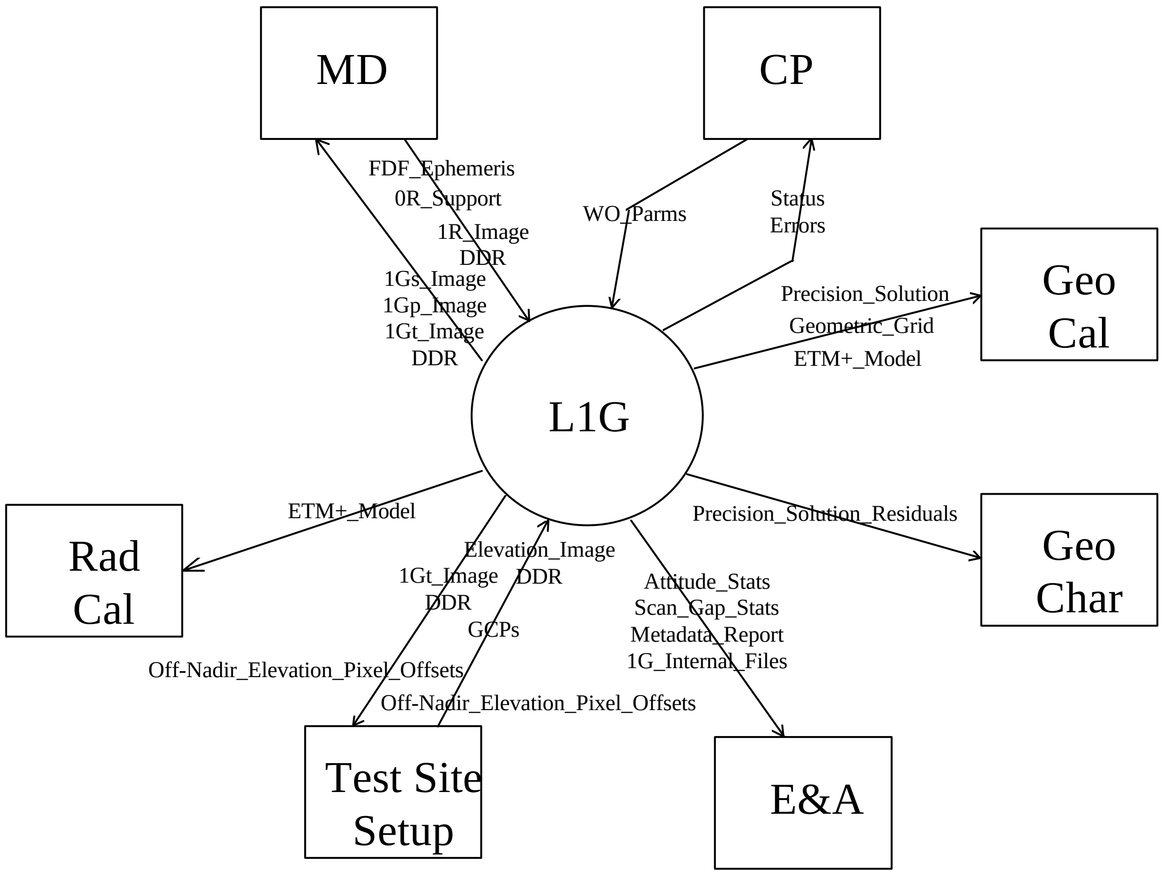


Figure 3-C Level 1 Geometry Context Diagram

3.1.1   FUNCTIONAL DESCRIPTIONS
Appendix B contains the L1G subsystem data flow diagram. The diagram shows the L1G subsystem's primary functions. Those functions are described in the subsections below. Appendix C contains the structure charts for each of the defined functions.

3.1.1.1 TMINIT
The tminit function initializes the ETM+ satellite model structure for a given ETM+ image and writes the structure to an ASCII file. The ETM+ model structure is initialized using the corrected PCD and MSCD files generated by the INGEST function. The ETM+ satellite model information is used to calculate geo-location information, sun angles, and a day/night indicator that will be compared to the same information in the metadata. This validates the

metadata and is also a check that the PCD and MSCD information can be used successfully. A report will be generated that will show the difference between the metadata and the IAS calculated information. If the deltas are too large or an error occurs in the IAS calculation an error message is displayed to the operator and processing is terminated.

Requirements Allocation
The following list maps the requirements to the TMINIT function:

> 3.2.2.3.1 The IAS shall be capable of processing payload correction data (PCD) data to correct spacecraft time, generate a sensor pointing model (attitude and jitter), and calculate spacecraft position and velocity (ephemeris).
>
> > 3.2.2.3.1-A The IAS shall generate a sensor pointing model from the PCD data.
> >
> > 3.2.2.3.1-B The IAS shall be capable of calculating spacecraft position and velocity information using the PCD ephemeris information
> >
> > 3.2.2.3.1-C The IAS shall be capable of calculating spacecraft position and velocity information using the definitive ephemeris information.
>
> 3.2.2.3.3 The IAS shall be capable of creating systematically corrected ETM+ Level 1G imagery from Level 0R products.
>
> > 3.2.2.3.3-A The IAS shall be capable of creating an ETM+ model from the Level 0R PCD and MSCD product, that will be used to generate systematically corrected ETM+ Level 1G imagery.
>
> 3.2.2.3.7 The IAS shall be capable of incorporating IAS-generated calibration coefficient updates to generate Level 1 data.
>
> > 3.2.2.3.7 -A The IAS shall be capable of incorporating values from the calibration parameter file in the generation of the ETM+ model.
>
> 3.2.2.3.12 The IAS shall be capable of processing mirror scan correction data (MSCD) to generate scan mirror and scan line corrector mirror models..
>
> 3.2.2.3.15 The IAS shall be capable of processing to Level 1R and 1G both ascending and descending passes ETM+ Level 0R data.
>
> > 3.2.2.3.15-A The IAS shall be capable of creating an ETM+ model that will account for an ascending pass information for the generation of a Level 1G..
> >
> > 3.2.2.3.15-B The IAS shall be capable of creating an ETM+ model that will account for a descending pass information, for the generation of a Level 1G.

3.2.2.4.12 The IAS shall be able to evaluate the quality of level 0R products. Quality checks will include but not be limited to those listed in Table 3.2.2.4-1.

3.2.2.4.12-A The IAS shall validate scene coordinates from the Level 0R metadata.

3.2.2.4.12-B The IAS shall validate Level 0R metadata WRS scene parameter correctness.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the model initialization process.

Algorithm Allocation
The following algorithms are allocated to the TMINIT function:

- Attitude Processing
- Create Model
- Call Model

Inputs/Outputs
Table 3-4 defines the inputs and outputs for the TMINIT function:

Inputs	Outputs
Work Order Parameters (WOPs)	ETM+ Model
Payload Correction Data (PCD)	Attitude Statistics
Mirror Scan Correction Data (MSCD)	Metadata Validation Report
Calibration Parameter File (CPF)	Error Status
Definitive Ephemeris	
Data Descriptor Record (DDR)	
Metadata	

Table 3-4: TMINIT Interface Table

3.1.1.2 TMGRID
The tmgrid function generates a ETM+ mapping grid that defines a transformation from the input image's satellite perspective to a user specified output projection. The relationship between the input to output space is defined in a geometric grid for each band. The grid is used by the geometric transformation function to transform or resample the image data into the output projection space (frame). The grid is generated by calling the geometric projection transformation package to transform the satellite coordinates

(calculated using the ETM+ satellite model), at each grid intersection, into the specified map projection coordinates. The transformation package is based on the U.S. Geological Survey's General Cartographic Transformation Package (GCTP).

Requirements Allocation
The following list maps the requirements to the TMGRID function:

> 3.2.2.3.3 The IAS shall be capable of creating systematically corrected ETM+ Level 1G imagery from level 0R products.
>
> > 3.2.2.3.3-B The IAS shall generate a grid using framing and projection parameters that map input space to projection output space for the generation of a Level 1Gs.
>
> 3.2.2.3.4 The IAS shall be capable of creating precision corrected ETM+ Level 1G imagery from level 0R products and ground control points (GCPs).
>
> > 3.2.2.3.4-A The IAS shall be capable of creating a precision grid from a precision updated model.
>
> 3.2.2.3.9 The IAS shall have the capability to produce a 1G product with a grid cell size that is variable from 15 to 60 meters, in increments of 1 millimeter (mm).
>
> 3.2.2.3.10 The IAS shall have the capability to map project 1G using the Space Oblique Mercator, Universal Transverse Mercator, Lambert Conformal Conic, Transverse Mercator, Oblique Mercator, and Polyconic coordinate reference systems.
>
> 3.2.2.3.11 The IAS shall have the capability to create a 1G image oriented to nominal path or north-up.
>
> 3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.
>
> > 3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the grid generation process.
>
> 3.2.3.5 The IAS shall contribute circular errors no greater than 1.8 m, 1 sigma, in the production of systematically corrected ETM+ Level 1G imagery. This error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.

Algorithm Allocation
The following algorithms are allocated to the TMGRID function:

- Geometric Griding

Inputs/Outputs

Table 3-5 defines the inputs and outputs for the TMGRID function:

Inputs	Outputs
Work Order Parameters (WOPs)	Geometric Grid
ETM+ Model	Error Status
Data Descriptor Record (DDR)	

Table 3-5: TMGRID Interface Table

3.1.1.3 TMRESAMPLE

The tmresample function rectifies an input image to output space by using a geometric grid to establish the relationship between the input space line and samples to the output space line and samples. Before the image can be resampled to the output space each input scan must be extended to the resampling kernel size and to account for gaps between scans. Once this is done, a pixel location in the input space is calculated for each pixel in the output space. Generally, the location in input space does not fall on an integer pixel location and the pixels surrounding this location are used to generate a new pixel value for the output space. How much the surrounding pixels contribute to the output pixel depends on the resampling method (cubic convolution, MTF, nearest neighbor, ...). The weights for the resampling method are generated and then adjusted to account for the detector delays of the surrounding pixels. An adjustment for terrain can also be incorporated at this time. This requires an elevation image in the same projection as the output space and a table that contains off-nadir elevation pixel offsets. This option should only be applied when using a precision grid. The resampling process generates a systematic (1Gs), precision corrected (1Gp - generated from a precision grid), or a terrain corrected (1Gt - generated from a precision grid and elevation data) image.

Requirements Allocation

The following list maps the requirements to the TMRESAMPLE function:

> 3.2.2.3.3 The IAS shall be capable of creating systematically corrected ETM+ Level 1G imagery from level 0R products.
>
> > 3.2.2.3.3-C The IAS shall be capable of creating a Level 1Gs using a geometric grid
>
> 3.2.2.3.4 The IAS shall be capable of creating precision corrected ETM+ Level 1G imagery from level 0R products and ground control points (GCPs).
>
> > 3.2.2.3.4-B The IAS shall be capable of creating a precision Level 1G image from a precision grid.

3.2.2.3.5 The IAS shall be capable of creating terrain corrected ETM+ Level 1G imagery from level 0R products, GCPs, and elevation data.

3.2.2.3.5-A The IAS shall be capable of creating terrain corrected ETM+ Level 1G imagery from level 0R products, elevation data, and a precision grid.

3.2.2.3.7 The IAS shall be capable of incorporating IAS-generated calibration coefficient updates to generate Level 1 data.

3.2.2.3.7-B The IAS shall be capable of incorporating values from the calibration parameter file in the generation of resampling weights.

3.2.2.3.8 The IAS shall support nearest neighbor, cubic convolution, and modulation transfer function (MTF) compensation resampling.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the resampling process.

3.2.3.3 The IAS shall contribute no greater than .7% uncertainty to absolute radiometric accuracy during the generation of level 1R and 1G data.

3.2.3.3-A The IAS 1G processing system will use floating point representations of pixel values to preserve absolute radiometric accuracy.

3.2.3.4 The IAS shall be able to create systematic imagery to a geodetic accuracy of 250 meters, 1 sigma, providing all inputs are within specification. Performance applies to along-track and cross-track directions, and is referenced to a nadir-viewing geometry.

3.2.3.6 The IAS shall provide the capability to register pixels from a band to the corresponding pixels of the other bands in a common scene to an accuracy of 0.28 sensor GSD, 0.9p, in along-track and cross-track directions providing all inputs are within specification. The accuracy is relative to the largest sensor GSD of the registered bands.

Algorithm Allocation

The following algorithms are allocated to the TMRESAMPLE function:

- Detector Delay Resampling Weights
- Resampling
- Terrain Correction

Inputs/Outputs

Table 3-6 defines the inputs and outputs for the TMRESAMPLE function:

Inputs	Outputs
Work Order Parameters (WOPs)	1Gs
1R Imagery	1Gp
Data Descriptor Record (DDR)	1Gt
Geometric Grid	Data Descriptor Record (DDR)
Calibration Parameter File (CPF)	Scan Gap Statistics
Elevation Imagery	Off-Nadir Elevation Pixel Offsets
Off-Nadir Elevation Pixel Offsets	Error Status

Table 3-6: TMRESAMPLE Interface Table

3.1.1.4 PRECISION

The precision function generates updates to the ETM+ model that adjust the satellite position, velocity, and attitude information. This is done by correlating a systematic image to a set of ground control point chips (GCPC) that have precise geo-location information attached. The differences (or residuals) between the calculated locations in the image (using the ETM+ satellite model) and the actual locations, (found by correlating the GCPC to the image) are used to calculate the updates to the ETM+ model. A minimum of sixteen well distributed GCPCs must have correlated to calculate the required update information. An outlier rejection scheme is also incorporated to eliminate any GCPCs that may have correlated to an incorrect feature in the image. A precision solution file is created that contains orbit and attitude updates as well as the pre-fit and post-fit residual solutions calculated in the precision process.

Requirements Allocation

The following list maps the requirements to the PRECISION function:

3.2.2.3.4 The IAS shall be capable of creating precision corrected ETM+ Level 1G imagery from level 0R products and ground control points (GCPs).

3.2.2.3.4-A The IAS shall create a precision updated model from ground control points.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the precision correction process.

Algorithm Allocation
The following algorithms are allocated to the PRECISION function:

- Precision Correction

Inputs/Outputs
Table 3-7 defines the inputs and outputs for the PRECISION function:

Inputs	Outputs
Work Order Parameters (WOPs)	ETM+ Model
1Gs	Precision Solution
Data Descriptor Record (DDR)	Precision Solution Residuals
Geometric Grid	Error Status
GCP Imagery	
GCP Tiepoints	
ETM+ Model	

Table 3-7: PRECISION Interface Table

3.2 GEOMETRIC CHARACTERIZATION SUBSYSTEM

The geometric characterization subsystem, characterizes the systematic and terrain corrected images to determine if there are any systematic errors as a result of processing or inaccurate input information (ephemeris, band offsets, ...). The geometric characterizations include characterizing the geodetic accuracy, geometric accuracy, correlation between bands, and correlation repeatability between images over that same area. The results of the characterizations will be used to ensure that the systematic meets its performance specifications, refine the calibration estimates, and will be analyzed to determine if there are any systematic errors that can be corrected by tweaking system parameters.

Requirements Allocation
The following list maps the requirements to the geometric characterization subsystem.

3.2.2.3.6 The IAS shall be capable of performing image to image registration.

3.2.2.4.8 The IAS shall be able to evaluate the geodetic accuracy of ETM+ Level 1G image data.

3.2.2.4.9 The IAS shall be able to evaluate the internal geometric accuracy of ETM+ Level 1G image data.

3.2.2.4.10 The IAS shall be able to evaluate the band to band registration accuracy of ETM+ imagery.

3.2.2.4.11 The IAS shall be able to evaluate the image to image registration accuracy of ETM+ data.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.3.7 The IAS shall contribute error no greater than 0.11 multispectral sensor GSD, 0.9p, along-track, and 0.24 multispectral sensor GSD, 0.9p, cross-track in the assessment of band-to-band registration.

3.2.3.8 The IAS shall provide the capability to perform image to image registration to an accuracy of 0.4 multispectral sensor GSD, 0.9p, in the along-track and cross-track directions providing all inputs are within specification.

3.2.3.9 The IAS shall contribute circular errors no greater than 3.6 m, 1 sigma, during image to image registration correction of ETM+ Level 1G data. Error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.

3.2.3.11 The IAS shall be capable of digitally correlating common features in separate bands of the same image or same bands of separate images to an accuracy of 0.1 pixel, 0.9p.

3.2.4.8 The IAS shall perform calibrations, **assessments** and evaluations with frequencies specified in Tables 3.2.4-1 and **3.2.4-2**.

Table 3.2.4-2. Frequency of Assessment Activities (geometric only)

Assessments	**Assessment Frequency**	**Reporting Frequency**
Geodetic accuracy	At most on 90-day intervals	Quarterly
Geometric accuracy	At most on 90-day intervals	Quarterly
Band-to-band registration accuracy	At most on 90-day intervals	Quarterly
Image-to-image registration accuracy	At most on 90-day intervals	Quarterly

Algorithm Allocation

The following algorithms are allocated to the geometric characterization subsystem:

- Geodetic Characterization
- Geometric Characterization
- Image-to-Image Characterization
- Band-to-Band Characterization

Interfaces
Figure 3-D illustrates the geometric characterization subsystem context and external interfaces. Appendix A contains the data dictionary for the geometric characterization context diagram.

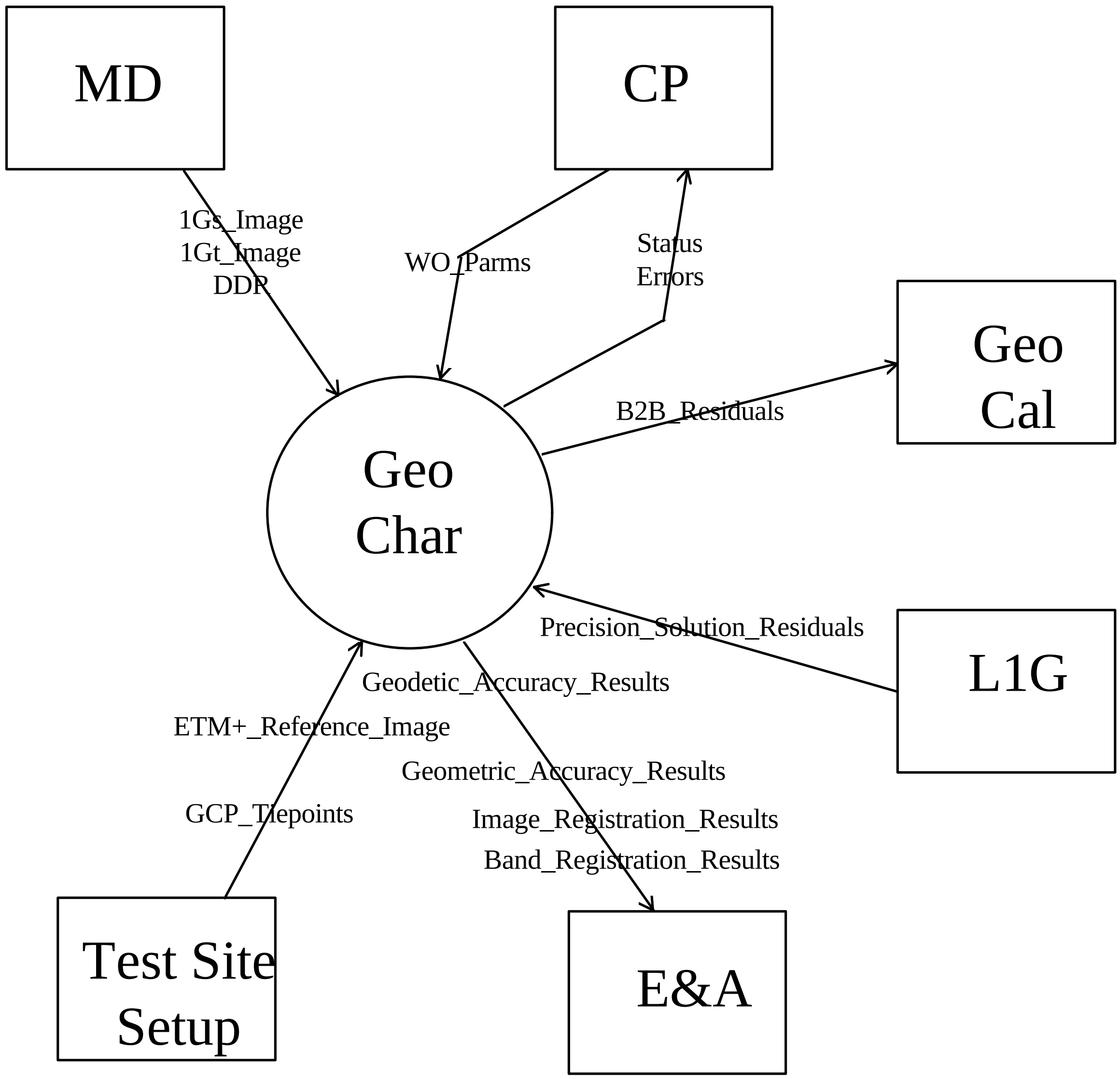


Figure 3-D: Geometric Characterization Context Diagram

3.2.1 FUNCTIONAL DESCRIPTIONS

Appendix B contains the geometric characterization subsystem data flow diagram. The diagram shows the geometric characterization subsystem's primary functions. Those functions are described in the subsections below. Appendix C contains the structure charts for each of the defined functions.

3.2.1.1 GEODETIC CHARACTERIZATION

The geodetic function verifies the absolute accuracy of the systematic (1Gs) and precision (1Gp) image by analyzing the ground control point residuals before and after the precision correction solution. Standard statistical error analysis on the pre-fit and post-fit residuals will be done to determine and generate a report of the absolute accuracy of the input image.

Requirements Allocation

The following list maps the requirements to the GEODETIC function:

> 3.2.2.4.8 The IAS shall be able to evaluate the geodetic accuracy of ETM+ Level 1G image data.
>
> > 3.2.2.4.8-A The IAS shall be able to evaluate the geodetic accuracy of systematically corrected 1Gs products (pre-fit).
> >
> > 3.2.2.4.8-B The IAS shall be able to evaluate the geodetic accuracy of precision corrected 1Gp products (post-fit).
>
> 3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.
>
> > 3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the geodetic characterization process.
>
> 3.2.4.8 The IAS shall perform calibrations, **assessments** and evaluations with frequencies specified in Tables 3.2.4-1 and **3.2.4-2**.
>
> > 3.2.4.8-A The IAS shall perform a geodetic accuracy assessment quarterly.

Algorithm Allocation

The following algorithms are allocated to the GEODETIC function:

- Geodetic Characterization

Inputs/Outputs

Table 3-8 defines the inputs and outputs for the GEODETIC function:

Inputs	Outputs
Work Order Parameters (WOPs)	Geodetic Statistics
Precision Solution Residuals	Geodetic Accuracy Report
	Error Status

Table 3-8: GEODETIC Interface Table

3.2.1.2 GEOMETRIC CHARACTERIZATION

There are three parts to the geometric characterization; visual inspection, plotting of the precision residuals, and polynomial fit of the precision residuals.

1. Visual inspection. The output image will be inspected visually for any geometric distortions. These distortions could include scan misalignment, artifacts produced from the resampling process such as ringing, or detector (line to line) discontinuity.

2. Plot of the residuals of the ground control points and their corresponding locations in the terrain corrected image. This can be either a vector plot indicating the lines/sample offsets or an image with the residuals color coded according to their magnitude superimposed on a paper product of the image.

3. A polynomial fit involving the ground control points and their corresponding locations in the terrain corrected output product. The polynomial fit will estimate the amount of scaling in x and y, rotation, offset in x and y, and non-orthogonal angle associated with a terrain corrected image. The residuals left after applying the polynomial coefficients to the terrain corrected x and y coordinates will represent any higher order distortions.

Requirements Allocation

The following list maps the requirements to the GEOMETRIC function:

3.2.2.4.9 The IAS shall be able to evaluate the internal geometric accuracy of ETM+ Level 1G image data.

3.2.2.4.9-A The IAS shall be able to display an image for visual inspection to detect geometric artifacts such as scan to scan misalignments.

3.2.2.4.9-B The IAS shall be able to assess the internal geometric accuracy of ETM+ imagery by display vector plots of the residual errors in 1Gt products measured from ground control points or reference images, for visual inspection.

3.2.2.4.9-C The IAS shall be able to detect and measure residual systematic distortions in 1Gt products including offset, scale, rotation, and skew errors.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the geometric characterization process.

3.2.4.8 The IAS shall perform calibrations, **assessments** and evaluations with frequencies specified in Tables 3.2.4-1 and **3.2.4-2**.

3.2.4.8-A The IAS shall perform a geometric accuracy assessment quarterly.

Algorithm Allocation
The following algorithms are allocated to the GEOMETRIC function:

- Geometric Characterization

Inputs/Outputs
Table 3-9 defines the inputs and outputs for the GEOMETRIC function:

Inputs	Outputs
Work Order Parameters (WOPs)	Polynomial Coefficients
Precision Solution Residuals	Geometric Accuracy Report
1Gs	Error Status
1Gt	
Data Descriptor Record (DDR)	

Table 3-9: GEOMETRIC Interface Table

3.2.1.3 IMAGE-TO-IMAGE CHARACTERIZATION

The image-to-image characterization function checks the registration quality between two images. The two images are assumed to be from the same band, same path/row taken at different times, and processed to the same level (e.g., either precision or terrain corrected). The two images are correlated at defined ground control points (GCPs) and a residual statistics report is generated. If the residuals or statistic information is above a predetermined threshold a message is sent to the operator for further analysis. The residuals and statistical information are saved for trending and analysis.

Requirements Allocation
The following list maps the requirements to the IMAGE-TO-IMAGE function:

3.2.2.3.6 The IAS shall be capable of performing image to image registration.

> 3.2.2.3.6-A The IAS shall perform image to image registration using rigorous sensor and platform models and ground control.

3.2.2.4.11 The IAS shall be able to evaluate the image to image registration accuracy of ETM+ data.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

> 3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the image to image characterization process.

3.2.3.8 The IAS shall provide the capability to perform image to image registration to an accuracy of 0.4 multispectral sensor GSD, 0.9p, in the along-track and cross-track directions providing all inputs are within specification.

3.2.3.9 The IAS shall contribute circular errors no greater than 3.6 m, 1 sigma, during image to image registration correction of ETM+ Level 1G data. Error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.

3.2.3.11 The IAS shall be capable of digitally correlating common features in separate bands of the same image or same bands of separate images to an accuracy of 0.1 pixel, 0.9p.

> 3.2.3.11-A The IAS shall be capable of digitally correlating common features in the same bands of separate images to an accuracy of 0.1 pixel, .9p.

3.2.4.8 The IAS shall perform calibrations, **assessments** and evaluations with frequencies specified in Tables 3.2.4-1 and **3.2.4-2**.

> 3.2.4.8-A The IAS shall perform an image-to-image registration accuracy assessment quarterly.

Algorithm Allocation
The following algorithms are allocated to the IMAGE-TO-IMAGE function:

- Image-to-Image Characterization

Inputs/Outputs

Table 3-10 defines the inputs and outputs for the IMAGE-TO-IMAGE function:

Inputs	Outputs
Work Order Parameters (WOPs)	Image-to-image Statistics
1Gt	Image Registration Report
Data Descriptor Record (DDR)	Error Status
ETM+ Reference Imagery	
GCP Tiepoints	

Table 3-10: IMAGE-TO-IMAGE Interface Table

3.2.1.4 BAND-TO-BAND CHARACTERIZATION

The band-to-band characterization function measures the offsets between bands of a systematically corrected image (1Gs). This is done by correlating windowed subsets between bands to determine the sub-pixel misalignments. The higher resolution bands will be reduced to the lower resolution band before correlation by using a pyramid pixel aggregation technique. All outliers from the correlation residual information will be removed and statistics will be calculated to measure all geometric shifts relating the measured offsets among all bands. This data is then used in the focal plane band-to-band calibration.

Requirements Allocation

The following list maps the requirements to the BAND-TO-BAND function:

> 3.2.2.4.10 The IAS shall be able to evaluate the band to band registration accuracy of ETM+ imagery.
>
>> 3.2.2.4.10-A The IAS shall be capable of characterizing the performance of the band center along-scan field angles by measuring residual band-to-band misregistration in the along-scan direction.
>>
>> 3.2.2.4.10-A The IAS shall be capable of characterizing the performance of the band center across-scan field angles by measuring residual band-to-band misregistration in the across-scan direction.
>
> 3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.
>
>> 3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the band to band characterization process.
>
> 3.2.3.7 The IAS shall contribute error no greater than 0.11 multispectral sensor GSD, 0.9p, along-track, and 0.24 multispectral sensor GSD, 0.9p, cross-track in the assessment of band-to-band registration.

3.2.3.11 The IAS shall be capable of digitally correlating common features in separate bands of the same image or same bands of separate images to an accuracy of 0.1 pixel, 0.9p.

3.2.3.11-B The IAS shall be capable of digitally correlating common features in separate bands of the same image to an accuracy of 0.1 pixel, .9p.

3.2.4.8 The IAS shall perform calibrations, **assessments** and evaluations with frequencies specified in Tables 3.2.4-1 and **3.2.4-2**.

3.2.4.8-A The IAS shall perform a band-to-band characterization accuracy assessment quarterly.

Algorithm Allocation

The following algorithms are allocated to the BAND-TO-BAND function:

- Band-to-Band Characterization

Inputs/Outputs

Table 3-11 defines the inputs and outputs for the BAND-TO-BAND function:

Inputs	Outputs
Work Order Parameters (WOPs)	Band-to-Band Statistics
1Gs	Band Registration Report
Data Descriptor Record (DDR)	Band-to-Band Residuals
GCP Tiepoints	Error Status

Table 3-11: BAND-TO-BAND Interface Table

3.3 GEOMETRIC CALIBRATION SUBSYSTEM

The geometric calibration subsystem estimates improved geometric processing parameters initially defined pre-launch in the calibration parameter file (CPF). This includes determining the alignment between the spacecraft navigation base reference and the ETM+ instrument, scan mirror profiles corrections, and band-to-band center location offset corrections. Any errors or corrections that need to be changed will become an update to one or more parameters in the calibration parameter file. This may require an analyst to evaluate characterization and calibration information to determine when the calibration parameter file should be updated and with what values.

Requirements Allocation

The following list maps the requirements to the geometric calibration subsystem.

3.2.2.2.1 The IAS shall be capable of determining the misalignment between the satellite navigational base reference and the ETM+ payload line-of-sight (LOS).

3.2.2.2.2 The IAS shall be capable of determining band-to-band registration parameters.

3.2.2.2.3 The IAS shall be capable of characterizing and updating along and across scan parameters (e.g., scan mirror profiles, scan-line corrector mirror profile, detector offsets, detector delays).

3.2.2.2.4 The IAS shall be capable of generating geometric calibration updates for the calibration parameter file.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.3.10 The IAS shall be capable of estimating the field angles to an accuracy of 0.18 arcsec, 1 sigma.

3.2.3.12 The IAS shall be capable of estimating the alignment of the ETM+ line-of-sight to the satellite navigation base reference to an accuracy of 24 arcsec, 1 sigma, in all axes.

3.2.4.8 The IAS shall perform **calibrations**, assessments and evaluations with frequencies specified in Tables **3.2.4-1** and 3.2.4-2.

Table 3.2.4-1 Frequency of Calibration Activities (geometric only)

Calibration Activity	Activity Frequency	Reporting Frequency
Sensor Alignment calibration	Once during IOC and at no more than 90 day intervals	Quarterly
Band-to-band registration	Once during IOC and at no more than 90 day intervals	Quarterly
Detector delay calibration	Once during IOC and at no more than 90 day intervals	Quarterly

Algorithm Allocation

The following algorithms are allocated to the geometric calibration subsystem:

- Sensor Alignment Calibration
- Scan Mirror Calibration
- Focal Plane - Band Placement Calibration

Interfaces
Figure 3-E illustrates the geometric calibration subsystem context and external interfaces. Appendix A contains the data dictionary for the geometric calibration context diagram.

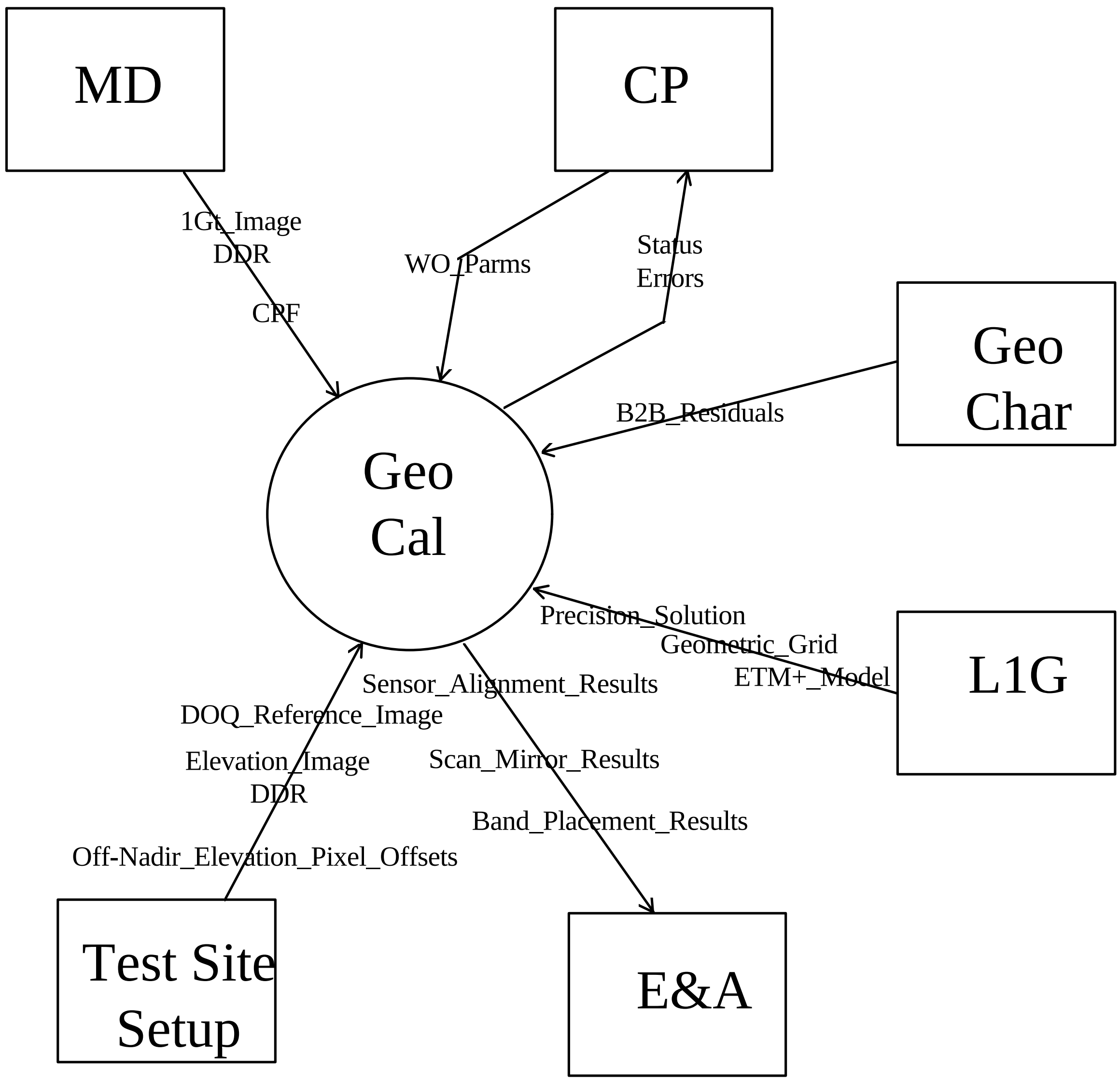


Figure 3-E: Geometric Calibration Context Diagram

3.3.1 FUNCTIONAL DESCRIPTIONS

Appendix B contains the geometric calibration subsystem data flow diagram. The diagram shows the geometric calibration subsystem's primary functions. Those functions are described in the subsections below. Appendix C contains the structure charts for each of the defined functions.

3.3.1.1 SENSOR ALIGNMENT CALIBRATION

The sensor alignment calibration function uses a sequence of precision correction solutions, to estimate the underlying ETM+ instrument to Landsat 7 navigation reference base alignment. The precision solutions must be generated from an image that was processed with definitive ephemeris data to help separate ephemeris position errors from angular alignment and attitude errors. Four files are created; the current state vector and covariance matrix information, orbit correction parameters, attitude correction parameters, and innovation (observation minus predicted observation) information. The information in these files will be used to determine if an update to the Calibration Parameter File (CPF) should be done and to create a new ETM+ alignment matrix for the CPF.

Requirements Allocation

The following list maps the requirements to the SENSOR ALIGNMENT calibration function:

> 3.2.2.2.1 The IAS shall be capable of determining the misalignment between the satellite navigational base reference and the ETM+ payload line-of-sight (LOS).
>
> 3.2.2.2.4 The IAS shall be capable of generating geometric calibration updates for the calibration parameter file.
>
> > 3.2.2.2.4-A The IAS shall be capable of generating updates to the sensor to spacecraft navigation base reference alignment matrix in the calibration parameter file.
>
> 3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.
>
> > 3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the sensor alignment calibration process.
>
> 3.2.3.12 The IAS shall be capable of estimating the alignment of the ETM+ line-of-sight to the satellite navigation base reference to an accuracy of 24 arcsec, 1 sigma, in all axes.

3.2.4.8 The IAS shall perform **calibrations**, assessments and evaluations with frequencies specified in Tables **3.2.4-1** and 3.2.4-2.

3.2.4.8-A The IAS shall perform a sensor alignment calibration quarterly.

Algorithm Allocation
The following algorithms are allocated to the SENSOR ALIGNMENT function:

- Sensor Alignment Calibration

Inputs/Outputs
Table 3-12 defines the inputs and outputs for the SENSOR ALIGNMENT function:

Inputs	Outputs
Work Order Parameters (WOPs)	State File
Calibration Parameter File (CPF)	Alignment Matrix
State File	Orbit Sequence
Precision Solution	Attitude Sequence
	Innovation Sequence
	Alignment Calibration Report
	Error Status

Table 3-12: SENSOR ALIGNMENT Interface Table

3.3.1.2 SCAN MIRROR CALIBRATION
The scan mirror calibration function uses a terrain corrected (1Gt) panchromatic image band and correlates a windowed portion of the image that is entirely within a scan with a reference image. The reference is the USGS digital orthophoto quadrangle (DOQ) imagery. The correlation points (predicted and actual) are mapped back to the input space and terrain effects are removed. The difference between the points in input space is the error in the scan mirror profile. A number of mirror error data points are generated for the forward and reverse scans and fit with a fifth order Legendre polynomials. If the difference between the actual mirror profile and newly calculated mirror profile is above a pre-determined threshold, an update to the Calibration Parameter File (CPF) will be initiated. The Legendre polynomials will be used to create new mirror profile coefficients for the CPF.

Requirements Allocation
The following list maps the requirements to the SCAN MIRROR calibration function:

3.2.2.2.3 The IAS shall be capable of characterizing and updating along and across scan parameters (e.g., scan mirror profiles, scan-line corrector mirror profile, detector offsets, detector delays).

3.2.2.2.3-A The IAS shall be capable of characterizing the performance of the scan mirror profiles for forward and reverse scans in the along-scan direction, as a function of scan mirror electronics number and bumper mode.

3.2.2.2.3-B The IAS shall be capable of characterizing the performance of the scan mirror profiles for forward and reverse scans in the across-scan direction, as a function of scan mirror electronics number and bumper mode.

3.2.2.2.3-C The IAS shall be capable of estimating improved values for the scan mirror profiles for forward and reverse scans in the along-scan direction, as a function of scan mirror electronics number and bumper mode.

3.2.2.2.3-D The IAS shall be capable of estimating improved values for the scan mirror profiles for forward and reverse scans in the across-scan direction, as a function of scan mirror electronics number and bumper model. (Note: Scan line corrector profile is not separable from across-scan scan mirror profiles.)

3.2.2.2.4 The IAS shall be capable of generating geometric calibration updates for the calibration parameter file.

3.2.2.2.4-B The IAS shall be capable of generating updates to the scan mirror profiles for forward and reverse scans in the along-scan direction, as a function of scan mirror electronics number and bumper mode in the calibration parameter file.

3.2.2.2.4-C The IAS shall be capable of generating update to the scan mirror profiles for forward and reverse scans in the across-scan direction, as a function of scan mirror electronics number and bumper mode in the calibration parameter file. (Note: Scan line corrector profile is not separable from across-scan scan mirror profile.)

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the scan mirror calibration process.

3.2.4.8 The IAS shall perform **calibrations**, assessments and evaluations with frequencies specified in Tables **3.2.4-1** and 3.2.4-2.

3.2.4.8-B The IAS shall perform an along-scan scan mirror parameter calibration quarterly.

3.2.4.8-C The IAS shall perform an across-scan scan mirror parameter calibration quarterly.

Algorithm Allocation
The following algorithms are allocated to the SCAN MIRROR function:

- Scan Mirror Calibration

Inputs/Outputs
Table 3-13 defines the inputs and outputs for the SCAN MIRROR function:

Inputs	Outputs
Work Order Parameters (WOPs)	Mirror Scan Statistics
1Gt	Mirror Profile Coefficients
Data Descriptor Record (DDR)	Mirror Calibration Report
DOQ Reference Imagery	Error Status
Elevation Imagery	
Off-Nadir Elevation Pixel Offsets	
ETM+ Model	
Geometric Grid	

Table 3-13: SCAN MIRROR Interface Table

3.3.1.3 FOCAL PLANE - BAND PLACEMENT CALIBRATION
The band placement calibration uses a set of the band-to-band characterization residual results to estimate the focal plane location of the eight ETM+ band centers. These estimates are used to update the band offsets in the Calibration Parameter File (CPF), if necessary. A band placement calibration report will also be generated that contains the original band-to-band characterization measurements, residuals, and the calibration solution vectors.

Requirements Allocation
The following list maps the requirements to the BAND PLACEMENT calibration function:

3.2.2.2.2 The IAS shall be capable of determining band-to-band registration parameters.

3.2.2.2.2-A The IAS shall be capable of estimating improved values for the band center along-scan field angles.

3.2.2.2.2-B The IAS shall be capable of estimating improved values for the band center across-scan field angles.

3.2.2.2.3 The IAS shall be capable of characterizing and updating along and across scan parameters (e.g., scan mirror profiles, scan-line corrector mirror profile, detector offsets, detector delays).

3.2.2.2.4 The IAS shall be capable of generating geometric calibration updates for the calibration parameter file.

3.2.2.2.4-D The IAS shall be capable of generating updates to the band center along-scan field angles in the calibration parameter file.

3.2.2.2.4-E The IAS shall be capable of generating update to the band center across-scan field angles in the calibration parameter file.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.2.6.13-A The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds for the band to band focal plane calibration process.

3.2.3.10 The IAS shall be capable of estimating the field angles to an accuracy of 0.18 arcsec, 1 sigma. (Note: This is 0.02 reflective GSD, 0.04 pan GSD, 0.01 thermal GSD.)

3.2.4.8 The IAS shall perform **calibrations**, assessments and evaluations with frequencies specified in Tables **3.2.4-1** and 3.2.4-2.

3.2.4.8-D The IAS shall perform an along-scan focal plane parameter calibration quarterly.

3.2.4.8-E The IAS shall perform an across-scan focal plane parameter calibration quarterly.

Algorithm Allocation
The following algorithms are allocated to the BAND PLACEMENT function:

- Focal Plane - Band Placement Calibration

Inputs/Outputs
Table 3-14 defines the inputs and outputs for the BAND PLACEMENT function:

Inputs	Outputs
Work Order Parameters (WOPs)	Band Center Locations
Band-to-Band Residuals	Band-to-Band Calibration Report
Geometric Grid	Error Status
Calibration Parameter File (CPF)	

Table 3-14: BAND PLACEMENT Interface Table

3.4 TEST TOOLS
These functions will be developed as test tools to modify input data and validate output data while developing and testing the IAS. These functions are not part of the IAS baseline, but will delivered with the IAS as byproducts of the development. The development will be based on creating a functional capability and will contain only minimal design and documentation.

3.4.1 Display Geometric Grid

This function will read and display the geometric grid generated from the TMGRID function. The supports to read the grid will exist as part of the IAS development, so the function need only convert the data to ASCII and format it for display to the user's terminal or to a file. A prototype of the display geometric grid was developed for the testing of ELIPS and should be very similar to it.

3.4.2 Display Data Descriptor Record

The data descriptor record (DDR) contains specific information related to an image; like the size, data type, number of bands, projection parameters… As part of the IAS development the supports to read and write the DDR information will exist, so the display DDR function need only convert the data to ASCII and format it for display to the user's terminal or to a file. This function exists in the Land Analysis System (LAS), but would need some modifications to support a band specific DDR implementation.

3.4.3 Display Off-Nadir Elevation Pixel Offsets

The Off-Nadir Elevation Pixel Offsets are tables of offsets generated over a geometric test site, for the line of site range from nadir to the edge of the image. An offset is calculated for each off-nadir location over the minimum and maximum elevation range within the test site. The elevation is incremented in 1 meter intervals. As part of the IAS development the supports to read and write the table will exist, so the display capability need only convert the data to ASCII and format it for display to the user's terminal or to a file. No prototype has been developed to display this table.

3.4.4 Display Ground Control Point (GCP) Tiepoints

The GCP tiepoints is a table of uniquely identified geo-location data points over a test site. As part of the IAS development, the supports to read the GCP tiepoints file will exist, so the display capability need only convert the data to ASCII and format it for display to the user's terminal or to a file. The functional capability exists in the LAS.

3.4.5 Display Definitive Ephemeris File

The definitive ephemeris is received from the Flight Dynamics Facility at GSFC. The format is defined in the interface control document between the MOC and IAS. As part of the IAS development supports to read the definitive ephemeris will exist, so the display capability need only format the definitive ephemeris for display to the user's terminal or to a file.

3.4.6 Display/Edit ETM+ Model

The ETM+ model file is generated in the TMINIT function. This file contains all the information needed to call the ETM+ model to calculate a latitude and longitude from an image line, sample, and elevation point. As part of the IAS development supports to read the ETM+ model will exist, so the display capability need only format it for display to the user's terminal or to a file. Since the ETM+ model file is already an ASCII file the user can use any editor to modify fields. The user would have to have a good knowledge of the ETM+ model structure to edit the file. If this method becomes too cumbersome a user interface would have to be developed to allow the user to specify which fields are to be modified. This may become an E&A tool in that case.

3.4.7 Extract/Read GCP Windows

Ground Control Point chips are windows of imagery surrounding a ground control point used in the precision correction solution. These chips are set up pre-launch over geometric test sites. The IAS will develop software to extract the GCP chips from a reference image for the chip creation. The amount of software to develop will depend on the source of the GCP imagery. LAS supports many image types and will probably be used to extract the initial chips. These chips will then be converted to HDF using the HDF library supports. If the GCP imagery is already in the HDF format, IDL can be used to extract the chips.

3.4.8 Extract/Read Elevation Windows

Elevation data is used to apply terrain correction to a precision corrected image and to remove terrain effects in some of the calibrations. The elevation imagery will be processed (pre-launch) for each geometric test site in a predefined projection. The capability to read and write windows of elevation imagery will exist in LAS. Some modification to this code will be made to support reading and writing HDF elevation files. If the elevation imagery is already in the HDF format, IDL can be used to create the elevation files.

3.5 TEST SITE SETUP

In support of the IAS operational system; a set of preprocessed ground control points, image chips, and elevation imagery must be created pre-launch or during IOC for each geometric test site. The procedures to create these data sets exist in LAS and will be used by the Digital Data Production (DDP) section at EDC. These procedures will be maintained by the IAS after IOC in the event that one or more test sites are added or changed that require the creation or recreation of these data sets.

3.5.1 Generate DOQ Reference Imagery

The Digital Orthophoto Quad data is used to determine if any adjustments are required to the mirror scan profile after launch. Each of the quads, over a test site, is mosaic together to form **TBD** complete scan lines. The resulting mosaiced image is in the same projection as the 1Gt calibration image. The procedures to generate the mosaic in the test site projection will be defined with LAS functions and run by DDP.

3.5.2 Generate Test Site GCPs (chips & tie points)

The precision correction process updates the satellite model by correlating a 1Gs image to a set of ground control point chips. For each chip a tie point location must be defined that ties the chip to a ground truth location. The residuals or delta differences between the ground control point and the 1Gs locations are used to calculate the model update values. The GCP chips will be extracted from high resolution imagery and re-projected into the test site projection using LAS functions. The ground truth information is determined from a map or using a GPS source. Each ground truth point will be tagged to a chip using LAS functions to create a tiepoint location file. The process of generating the chips and tagging them to a geo-location will be done by DDP.

3.5.3 Generate Test Site Elevation Images

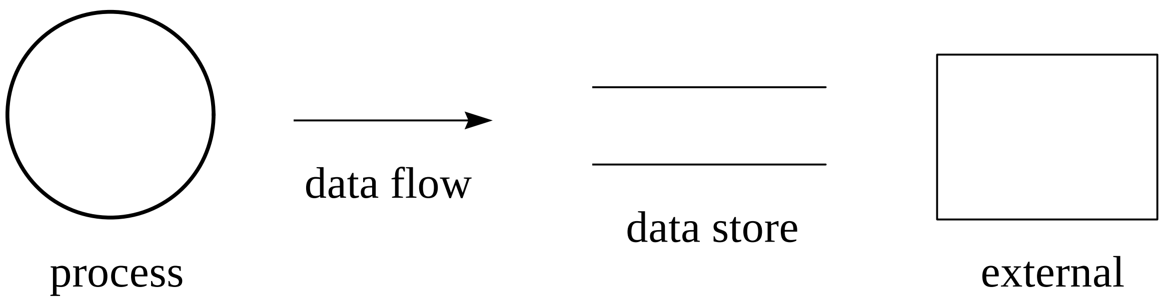
Elevation imagery is used in the terrain correction process of the resampling and to remove terrain effects for the mirror scan profile calibration. The elevation image must be in the same projection as the output 1Gp image. For each of the test sites the elevation imagery is extracted and re-projected into the test site projection. The elevation test site processing will be done by DDP.

APPENDIX A: CONTEXT DIAGRAM DATA DICTIONARY

0R_Support	= Metadata + PCD + MSCD + CPF
1G_Internal_Files	= Geometric_Grid + ETM+_Model + DDR
1G_Product	= [1Gs_Product | 1Gp_Product | 1Gt_Product]
1Gp_Product	= 1Gp_Image + DDR
1Gs_Product	= 1Gs_Image + DDR
1Gt_Product	= 1Gt_Image + DDR
1R_Product	= 1R_Image + DDR
Band_Placement_Results	= Band_Center_Locations + B2B_Calibration_Report
Band_Registration_Results	= B2B_Stats + B2B_Residuals + Band_Registration_Report
Cal_Results	= Sensor_Alignment_Results + Scan_Mirror_Results + Band_Placement_Results
Char_Results	= Geodetic_Accuracy_Results + Geometric_Accuracy_Results + Image_Registration_Results + Band_Registration_Results
DOQ_Reference_Image	= DOQ_Mosaic + DDR
Elevation_Data	= Elevation_Image + DDR + Off-Nadir_Elevation_Pixel_Offsets
ETM+_Reference_Image	= 1Gt_Image + DDR
GCP	= GCP_Imagery + GCP_Tiepoint
GCP_Tiepoint	= GCP_Position + GCP_Description + GCP_Stats
Geodetic_Accuracy_Results	= Geodetic_Stats + Geodetic_Accuracy_Report
Geometric_Accuracy_Results	= Poly_Coefs + Geometric_Accuracy_Report
Image_Registration_Results	= I2I_Stats + Image_Registration_Report
L1G_Stats	= Attitude_Stats + Scan_Gap_Stats + Metadata_Report
Precision_Solution_Residuals	= GCP_Residuals + GCP_Residuals_Pre_Fit + GCP_Outliers
Reference_Image	= [DOQ_Reference_Image | ETM+_Reference_Image]
Scan_Mirror_Results	= Mirror_Scan_Stats + Mirror_Profile_Coefs + Mirror_Calibration_Report
Sensor_Alignment_Results	= Alignment_Matrix + State_File + Orbit_Sequence + Attitude_Sequence + Innovation_Sequence + Alignment_Calibration_Report
Geodetic_Accuracy_Report	= Text file containing results of geodetic accuracy assessment including the accuracy test results contained in the Geodetic_Stats data flow and a presentation of the control point locations and residuals extracted from the Precision_Solution_Residuals data flow, both as tabular data and as vector plots.

Image_Registration_Report	= Text file containing results of Image to Image registration assessment including summary statistics from I2I_Stats data flow and the image to image tie point locations and residuals from the I2I_Residuals data flow, presented in tabular for and as vector plots.
Geometric_Accuracy_Report	= Text file containing results of Geometric Accuracy assessment including analyst notes from the Visual_Stats data flow, GCP locations and residuals from the GCP_Residuals data flow (pre-polynomial fit), and post-polynomial fit GCP residuals from the Poly_Residuals data flow. Residuals are presented both in tabular form and as vector plots. The report may also contain image windows portraying anomalies identified by the analyst.

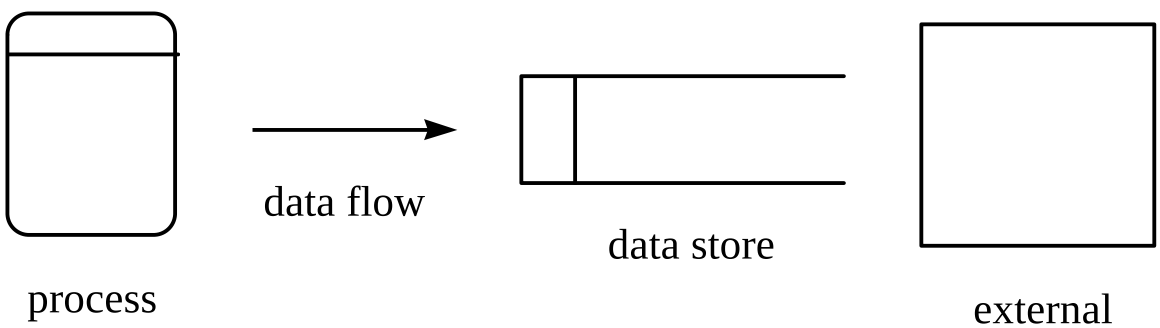
CONTEXT CHART SYMBOLS:



APPENDIX B: GEOMETRIC SUBSYSTEM DATA FLOW DIAGRAMS

- GEOMETRIC SUBSYSTEM
- LEVEL 1G
- GEOMETRIC CHARACTERIZATION
- GEOMETRIC CALIBRATION

DATA FLOW SYMBOLS:



APPENDIX C: STRUCTURE CHARTS

LEVEL 1G

- TMINIT
- TMGRID
- TMRESAMPLE
- PRECISION

GEOMETRIC CHARACTERIZATION

- GEODETIC
- GEOMETRIC
- IMAGE TO IMAGE
- BAND TO BAND

GEOMETRIC CALIBRATION

- SENSOR ALIGNMENT
- SCAN MIRROR CALIBRATION
- BAND TO BAND FOCAL PLANE

STRUCTURE CHART SYMBOLS: